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Contents

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The cover photograph shows a rehearsal for the programme 'Grandstand' in Studio E at the Lime Grove studios in London.

The major contributions are preceded by individual lists of contents.

Editorial

The March of Video Tape

The beginnings of Video Tape Recording

In 1956 the American firm of Ampex announced their invention of the so-called quadruplex video tape recorder. The term quadruplex simply meant that the recording drum possessed four video heads. By causing these heads to write transversely on 2-in. magnetic tape they achieved an effective writing speed of 1500 in. per second. This format was to prove by far the most successful of all the systems proposed at that time and indeed it is the only standard at present recognised by broadcasting authorities. Prior to this invention the only method of recording the output from a television studio was on photographic film. With the advent of the magnetic-tape video recorder a new degree of freedom was available to the television director, who was able to see an immediate replay of his programme. Even in those early days the quality of reproduction was better than any other recording system then available. When dreams about colour television started to become a reality it was apparent that film telerecording in colour was likely to be very expensive if it could be achieved at all. The BBC therefore concentrated on video tape recording and encouraged Ampex to improve their system so that the video tape recorder would have an acceptable performance on the more stringent 625-line system. In co-operation with Ampex a new recording standard was evolved which became known as the 'high band standard' and which was able to record the 625-line PAL colour signal. These efforts were very successful and present-day recorders still use the standards evolved at that time. So effective is the modern video tape recorder that it requires an educated eye to discern the difference between the recording and the original. Because of the versatility of the modern VTR it is perhaps not surprising that directors have taken full advantage of the system and it is now normal practice to record a number of sequences from the studio which in turn will be edited together to make a final programme. Indeed the ability to assemble their programme, during an editing session from a small or large number of takes is at least partly responsible for the sophisticated programmes which we see on our screens today. However, this ability to edit is not without its drawbacks for it does mean that the transmission tape is often the third generation copy (sometimes even higher) and therefore the degradations added by the recording system are beginning to mount up. That the present-day programmes recorded on magnetic tape are generally accepted as being of very high quality is due in part to the highly-developed recording equipment but is also a tribute to the skill of and care taken by the recording engineers.

VTRs in the BBC

There are, at the moment, forty-eight colour video tape recorders in operational service in the BBC. Thirty-three of these machines are in London, eight in the Regions, and seven are mobile colour VTRs. Concentrating upon the Television Centre, the facilities installed there are at least as comprehensive as anywhere in the UK and probably in Europe. The earlier VTR channels were equipped in such a way that they could be regarded as universal channels including the ability to work on other television standards than our own. Later channels have become more specialised and a number of machines are arranged as editing pairs. In order to minimise breakdowns and to maintain the highest quality on transmission two network transmission rooms were installed, each equipped with two recorders. The requirements of editors of sports programmes (especially those on Saturdays, which are discussed in an article in this issue) led to the installation of a control desk making it possible for material from any of six video tape recorders to be switched 'on air' to one line during a programme. Sports programmes, as well as light entertainment and other programmes, make considerable use of the video disk recorders, which can record some 30 seconds of programme material and replay it at normal speed, twice normal speed, or in slow motion at any rate from normal speed to stand-still.

Video Tape Editing

The editing of video tape, which is also dealt with in this issue, is a field in which there is at present perhaps more technical activity than in any other part of the recording system. In the early days the only method of editing a video tape was by exactly the same method as is used for audio tapes, that is to cut the tape and rejoin it to another tape; with the additional complication that the video and sound edit points are widely separated. Despite the expertise in editing acquired by a number of video tape engineers, this was clearly a drawback of the magnetic recording system. The so-called electronic editor unit, 'Editec', enabled edits between different tapes to be rehearsed and then executed without physical splicing but it was still a time-consuming operation. The arrival of time code editing enabled edits to be made at predetermined frames, and to be rehearsed without erasing any material. Additional

facilities, such as vision faders and the ability to control a number of other machines external to the cubicle, have given the (human) editor the nearest approach to a comprehensive editing suite yet.

Tape Storage

It is perhaps not surprising that with the large number of video tape recorders and a natural desire of the programme departments to store their programmes, the total number of recorded hours on tape held in the tape library now exceeds 20 000. The sheer volume of tape causes an increasing storage problem – the weight of the tapes to date being something in the region of 400000 lb! To achieve the present high quality of magnetic recording an increasing amount of tape servicing takes place. When a tape has been reviewed for possible damage (drop-out, tape deformation, etc.) it is rewound, taking care to ensure that it is wound evenly throughout its length. The tape must then be stored in controlled conditions of temperature and humidity, and even so when it is again withdrawn from the library it should be allowed to acclimatise in the main tape area before being replayed.

Video Head Wear

Another factor of video tape recording is the video heads themselves. The actual process of recording is akin to passing the video head over fine but very abrasive material. With the VTRs now in use the video head is worn out (on average) after 250 hours of recording. These heads can then be reworked and new video head tips inserted in them. This, however, is only part of the story, for to maintain the very high degree of compatibility that is desired each head is carefully examined before being entered into service.

Helical Scanning Machines

The helical-scanning VTR's, which have lately become available, are cheaper than the quadruplex machines and their tape costs are lower, but their standards and reliability have not so far been adequate for full broadcasting use. The BBC, however, are at present appraising a new generation of helical-scanning machines, using 1 in. or 2 in. tapes in different examples, which may well prove acceptable for at least some broadcasting applications while retaining the advantages of lower capital and tape costs offered by earlier helical machines, as well as promising much longer recording-head life. To produce a multi-generation tape which is good enough for transmission requires very stringent standards indeed, and although the new machines are relatively untried it may be that they will have an important application in broadcasting.

The Audio Track

The audio track presents many problems to the video tape editor, for although it can be edited separately from the video track, should the editor wish to change the time relationship between audio and video, then the audio material must be dubbed on to a standard audio recorder and then re-recorded on to the video tape. As the complexity of the audio operation has increased a demand for a more comprehensive audio dubbing suite has arisen. This demand will be met later this year, when a new dubbing theatre is installed in Television Centre. This will be equipped with all the usual facilities but in addition will include a multi-track audio recorder capable of being synchronised with a video tape recorder. The new dubbing theatre will thus provide audio facilities equal in many respects to those already existing for video.

Archives of the Future

Magnetic video recording has proved to be a very reliable and universally-accepted recording medium for Television. So far magnetic tape recordings have shown little or no deterioration with the passage of time; indeed they are expected to have greater long-term stability than colour film stock. Future generations will therefore have access to an ever-increasing library of television material ranging from present-day drama to programmes commenting on many facets of present-day life. It would indeed be interesting to know what conclusions future hitorians may draw from such a wealth of materials, assuming that machines to play back the present standards continue to be available and in working order!

From Manual Splicing to Time Code Editing

G. R. Higgs, B.Sc(Eng.)

Video Tape Editor, Television Recording Department

Summary: The development of video tape editing from physical splicing of the tape to electronic editing of programme material was straightforward and understandable, but the continued development of electronic editing is perhaps less straightforward. The aim of complete control and total frame accuracy has now been achieved with the introduction of time code as applied in the most recent equipment, and this has inevitably led to greater complexity. Time code has, however, other uses and is applied over a wide range not necessarily concerned with editing. Developments in video tape editing systems are still in progress with an ever-widening choice of hardware appearing on the market, and this article traces the course of these developments in the Video Tape Section at the BBC Television Centre in London.

Contents

1 Physical splicing of tape

Video tape recording of television programmes in the BBC dates from about 1958. The early requirement was rapid turn round of material (e.g. for sports programmes covering more than one event) or recording of programmes at times more convenient than their scheduled transmission hours.

Naturally it was not long before the desire to modify the existing recording before transmission initiated the first steps in 'editing' of the video tape. These first edits were made by cutting and joining the tape during black level – typically a fade down (edit), and fade up – and were not undertaken lightly. With the crude facilities then available an edit could take up to half an hour and was an irreversible operation similar to cutting film negative.

Techniques and equipment improved and editing a picture to make a 'camera cut' became commonplace. On video tape, the sound and vision are physically displaced by 15 frames (0·6sec) with the vision head preceding the sound head as the film gate precedes the sound head in a 'comopt' or 'commag' film projector. The 0·6sec of sound track preceding the splice must therefore carry the sound associated with the picture following the splice; this section of track can be transferred by copying it on to a separate ¼in. tape and re-laying it on the sound track of the video tape preceding the cut. This is possible because a broadcast video tape machine can record 'audio only' on the sound track while replaying the vision.

This facility has other uses as may be seen later.

There was a period of consolidation and extension of these techniques to a point where complex operations were under-

taken by physical cutting and splicing of the video tape. Programmes began to be written, planned and recorded for editing to create production transitions not possible with 'live' or 'non-stop recording' productions.

Physical edits are butt joins made using a specialised metal-foil adhesive tape about ¼in. wide and only 0·00025in. thick, positioned across the back of the join. With modern microscope splicing blocks, joins were regularly made with normal accuracies of about 0·0005in., positioned during the field blanking period of the recorded signal.

As manufacturers improved the quality of the machines, the video head assemblies became increasingly more delicate and sensitive, and the thickness of the splicing tape at physical joins now became a significant factor. Good edits would replay satisfactorily but problems were encountered with their ability to withstand many playings over a period of time. Slight disturbances were also sometimes noticeable on copies of programmes at points where the original had appeared to replay an edit quite satisfactorily.

The advent of colour increased demands on the system and reduced tolerances still further.

During this period some experience was being gained with an electronic editor fitted to a monochrome machine. This was very much aided by the interest of one or two drama directors keen to make it work and willing to accept the inevitable development problems and set-backs.

2 Electronic editing

A normal machine switched to record at a given point during replay produces a totally unacceptable disturbance (loss of vision, syncs and colour) for anything from 2 to 10sec. If it can be made to switch from replaying to recording in such a manner that the resulting transition appears as a camera cut, an electronic 'in' edit will have been made. The device added to a machine to achieve this is called an Electronic Editor (Ampex) or Electronic Splicer (RCA), and it controls the transition in such a way that erasure, servo switching, signal switching and audio changeover take place in the correct sequence at precisely the correct times to produce on the tape a 'synthetic' camera cut. The process can be reversed to produce an 'out' edit—a transition from recording to replay of material already recorded on the tape.

Electronic edits immediately dispose of:

(*a*) splicing of tape and associated tape handling problems,

(*b*) the problem of staggered vision and sound heads. Since the electronic edit is time-controlled the vision and sound changeovers can be initiated simultaneously.

The electronic editor demands first-class performance from virtually all the machine's sub-sections: the signal system, audio system, control system and particularly the servo system. It can be set to control both sound and vision together or 'vision only', leaving the sound unaltered.

2.1 Positioning the Edit Manually

Electronic editing is usually carried out during the copying of the originally-recorded material on to a fresh tape so as to assemble it in programme order. Editing from live sources or others not on tape *is* done, but not commonly. Timing the incoming material is normally achieved by setting back the editing and replay machines the same time from the chosen transition points and starting both simultaneously.

The Electronic Editor has a turn on (or turn off) sequence lasting 15 frames. When an 'in' (or 'out') edit is initiated the actual transition on the tape occurs 15 frames later. On an 'in' edit this arises because the existing material must be erased from the tape before new information can be recorded and the video erase head is situated 15 frames upstream from the video record/replay head assembly. Thus initiating the 'in' edit immediately turns on the erase: the wiped tape moves on, and 15 frames later video recording – and sound if required – begin when the wiped tape reaches the recording heads. For an 'out' edit the erase is turned off immediately but the record/replay head must go on recording until the 15 frames of wiped tape between the two heads have been filled in, and the record/replay head switches to replay at the moment when the 'old' recording reaches it.

Early electronic edits were positioned by marking the back of the tape 15 frames before the required edit point and pressing the record button as the mark reached the vision head. A rather hair-raising experience at the time but nevertheless sequences such as complete intercut telephone conversations were edited in this manner! A rehearsal of the proposed edit could only be made by observing two monitors or by switching the monitoring at the proposed point. After a satisfactory 'rehearsal' the process was repeated but with the record button pressed 15 frames early!

2.2 Control of the Electronic Editor

2.2.1 Editsure

The first 'programmed' electronic editing on BBC video tape machines was 'Editsure'. Both machines were set back about 20sec from the desired points and started simultaneously. Editsure counted reference frame pulses and after a count of 485 started the Electronic Editor. The 'in' edit then occurred exactly 20sec from the start point. The Editsure control panel contained 'Play', 'Rehearse' and 'Edit' buttons. If 'Rehearse' was pressed rather than 'Edit' then only the monitoring (vision and sound or vision only as required) was switched at a count of 500.

This system gave repeatability on each run-up (within the 1 or 2 frame tolerance of machine lock-up) and was a great step forward. The system also provided that when the Editor was in the 'Vision only' mode it was possible to initiate 'sound record' manually. Artistically this was a great improvement. Many of the problems of VT editing are concerned with the sound track and there are numerous occasions when the desired sound transition point is not coincident with the vision. 'Out' edits could still only be made by pressing the editing machine 'stop' button whereupon the 'out' edit occurred 15 frames later.

Editsure was extensively used, particularly on the 405-line system. On this system the video tape cue track was not available because the tape width was required for video information. This arose due to the longer line time of the 405-line system (98μsec as against 64μsec) coupled with the poorer stability of the video head assemblies and associated servo systems. With the change to 625-lines and more stable machines the cue track became available for clean effects, guide tracks or control signals for electronic editing purposes.

2.2.2 Editec

The device called Editec, which was marketed by Ampex Corporation, was the first commercially-produced means for controlling the Electronic Editor to enable the edit point on the edit tape to be made precisely on the desired frame. Editec achieves this by storing edit-point information in the form of edit cues recorded on the cue track. It is important to realise that Editec controls the Electronic Editor; it does not directly control the machine to make the edit. The cues are 10msec bursts of 4kHz tone (i.e. 40 cycles at 4kHz) and are keyed on to the cue track by pressing a cue button. They are recorded by the normal cue track record/replay head at a time coincident with the required edit point. Replayed by this head they would be useless for initiating Editor turn-on since the edit would occur 15 frames later. They are therefore read off by an auxiliary 'cue read-off' head situated 'upstream', just before the video erase head assembly. This is the only practical position but means the cues are now read off 33 frames before the point in programme time at which they were recorded. Therefore after cue read-off Editec counts 18 frames then initiates the Editor turn-on cycle. Fifteen frames later the edit occurs precisely at the required frame, that is just as the edit cue reaches the cue track record/replay head.

As a by-product of Editec having to 'mark time' for 18 frames, the edit point can be altered to occur earlier than the time defined by the edit cue, without changing the cue position on the tape. If Editec is set to minus 7, it counts only 11 frames before starting the Editor, the edit occurring 26 frames after cue read-off instead of 33, that is 7 frames early. The maximum shift possible is obviously minus 18 frames. For operational symmetry Editec can also delay the edit up to 18 frames. There is of course no technical reason why the delay cannot be as long as required.

With Editec a second cue can control the Editor turn-off in such a way that a new piece of vision (and sound if required) can be 'inserted' into existing material.

Editec has various facilities. Rather than merely altering the edit point relative to the cue one can actually erase the cue and record a new cue at the new edit point selected. Cues can be selected out of a series of cues, selectively erased, or made to operate external equipment, and the machine can be set to record automatically a sequence built up from any number of 'takes' of anything from 1 to 36 frames duration. After the machine stops and is rewinding for the next 'take', the picture determining the vision input to the machine is altered to produce the required effect in the 'animation'. As each pass takes about 20sec, a 1min animated sequence made 8 frames at a time takes just over an hour. If the machine is manually restarted each time, of course the time taken becomes indeterminate.

3 Time Code

In 1968 time code made its first appearance on trial with BBC video tape machines. Time code is a digital signal containing 80 bits per television frame coded as bi-phase mark and recorded on the VTR cue track. The code uniquely defines (or addresses) every frame on the tape in hours, minutes, seconds and frames. The signal originates from a time code generator and can be distributed to any number of machines. The generator is normally locked to the colour subcarrier of a pulse chain and should strictly be recorded only on machines recording vision derived from the same pulse chain. The generator normally produces real time, resetting at 24.00 hours.

3.1 Time Code Editing

Each VTR to be controlled has a programmer with 'start' and 'stop' memories which may be used to control the tape transport or (if fitted) the Electronic Editor. The time code used can be the machine's own cue track time code, another machine's cue track time code or any external time code including the distributed 'time of day' code.

To choose required points the programmers have a display 'Hold' control that 'freezes' the display of the time code being used for as long as required. Facilities are provided for the display of time codes stored in 'start' and 'stop' registers.

3.1.1 On Time

The fundamental difference using time code is that continuous information is available. Circuits can 'foresee' requirements rather than being 'taken by surprise' by the sudden appearance of a command pulse (such as an edit cue). This means that logic systems can detect inconsistent commands and conflicting requirements, and therefore can either indicate these errors or refuse to operate on them, as appropriate.

The first trial system was called 'On Time' and used prerecorded time code on the editing VTR to:

1. control the Electronic Editor
2. control the starting of the replay machine.

The programmer on the editing VTR replaced Editec and controlled the Electronic Editor, while the replay machine programmer controlled the replay machine tape transport.

The edit point address was entered in the 'start' register of the programmer of the editing VTR and an address say 10sec earlier in the 'start' register of the replay machine programmer. This machine was then parked manually 10sec before the required transition point. The edit machine was run from a point earlier than 10sec before the edit point, and both programmers were fed the replayed cue track time code from the edit machine. At 'minus 10sec' the replay machine started and locked up under its own servo. Achieving the right 'in' point to the replay tape depended on accuracy in parking the tape at a point 10sec upstream. If the replay tape also carried a time code, accurate parking could be achieved by entering a time 10sec earlier than the replay tape code at the required point into the replay programmer 'stop' register. Playing the tape from before this point would automatically stop the machine at the right point. The replay programmer was then switched to edit-machine time code and the operation continued as for 'manual' parking.

'Out' edits were made by entering the correct code in the editing programmer 'stop' register.

Rehearsal was achieved by pressing the programmer 'operate' button only, while an edit was made by pressing the edit machine record button when it had locked up.

A programme control determined whether audio-video or video-only edits were made.

'On time' could be used to control tape transports from 'time of day' code to start and stop machines at precise times,

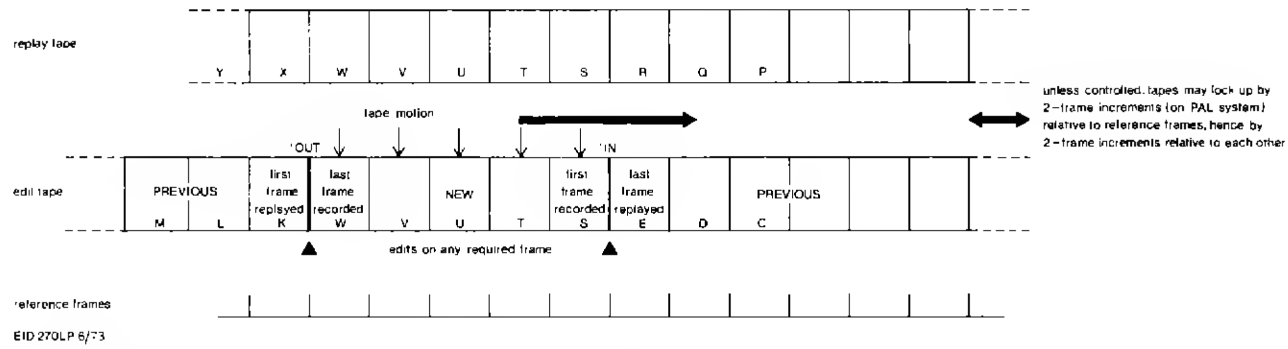


Fig. 1 Relation of replay to edit tape. In this example the insert is of five frames only

a second machine could be started from the time code of the first machine for changeovers accurate to one frame.

3.1.2 Precise control of edit points

Both 'Editec' and 'On time' suffer the same disadvantage that even with very accurate parking of the replay machine the first frame recorded on the edit machine may commonly vary by ± 2 frames. This is due to the randomness of lock-up of both machines relative to the same reference sync-pulse chain. In the PAL system this relative lock-up can only alter by multiples of 2 frames, whereas when editing 525-line NTSC, increments of 1 frame may occur. Thus despite the exact frame accuracy of the edit point on the edit tape, the 'incoming' material does not match this precision. Where 'simultaneous start' is not used and one machine, already running, is used to start the other, there is still a ± 2 frame tolerance on its lock-up with respect to reference frames. The relation of the replay to the edit tape on 'in' and 'out' edits is shown in Fig. 1.

The manufacturers of 'On time' (EECo – Electronic Engineering Company) developed a system whereby the replay machine is controlled during run-up to ensure that both replay and edit machines reach their selected frames at the same time. With hindsight this may seem a rather simple, fundamental requirement but its realisation involves logic of considerable complexity. Its eventual development can be ascribed to:

1. The demand for ever-increasing accuracy of video tape editing.
2. The availability of cheap, small, low power logic systems (i.e. digital, integrated circuits).

As with 'On time' each machine has a programmer but its facilities are much extended. The edit programmer controls not only the Electronic Editor but also the edit-machine tape transport. The replay programmer controls the replay machine transport logic *and* has override control of the replay machine's capstan speed.

It is necessary for time code to be recorded on both edit and replay tapes. The selected edit point is entered in the edit programmer 'start' register (the 'out' point is entered in the 'stop' register if 'insert' is required). Pressing 'Recue' parks the edit machine 20sec, 00 frames before 'start' time. The selected 'in' point on the replay machine is entered in its programmer's 'stop' register. With the replay programmer in 'slave' mode – recuing the machine will park it 15sec 00 frames earlier. To relate the two programmers the edit-machine edit point (the edit 'start' time) is also entered in the replay programmer 'start' register. Thus this programmer now knows the edit point:

(*a*) on the edit tape relative to the edit machine time code.
(*b*) on the replay tape relative to its own machine time code.

When the edit machine is started for rehearsal or edit the replay programmer is also fed edit machine time code. Having parked the replay tape 15sec before the required point ('stop' time) the replay programmer starts the replay machine 15sec before its 'start register' time. (For this operation accurate parking of the edit machine at minus 20sec is unnecessary).

Synchronisation

If the replay machine achieved play speed in zero time and all machines always locked up the same way no further action would be necessary. (That however would make 'Editec' or 'On Time' repeatably exact!) The algebraic difference between the replay programmer's 'start' and 'stop' registers represents the relation required between the two tapes as they approach the edit point. This is a fixed figure and by differencing the two time codes every frame (dynamic subtraction) the replay programmer develops an error signal (i.e. the 'difference' between the required and actual differences). The error signal is used to override the replay machine capstan speed until zero error is achieved, the 'synchroniser' lights a 'sync' indicator and releases control of the replay capstan, and the machine servo then completes fully synchronous lock-up, having been left within less than a field of the correct frame.

Since the replay machine starts from rest when the edit machine is already 'at speed' the synchroniser always has to accelerate the replay tape above speed to catch up. The synchroniser only considers frames and 'frame differences'; if an error of one or more seconds is introduced this will be ignored and only the correct frames synchronised. As the tapes are parked accurately by the programmers this should not represent a problem.

If programmed to synchronise frames of opposite PAL switching a 'PAL ERROR' indicator will light. It is necessary to change either the edit or replay tape 'in' point by one frame. If ignored the selected frames will be synchronised but on release of capstan override the replay machine servo will reframe to a correct PAL frame. This will give an 'in' point error of ± 1 frame.

It can be seen that the replay programmer is dealing with two different time codes to control the tape replay whereas the edit programmer uses only one to park the edit tape and control the Electronic Editor.

The edit tape either has time code pre-recorded or continuous time code may be built up during editing by use of a second time code generator. This generator slaves itself to the edit machine during replay allowing the assembly of a continuous time code on the cue track as the programme is assembled on the sound and vision tracks. If preset to zero at the beginning of programme it gives immediate and continuous 'programme duration so far' during editing, a very useful asset.

The discerning reader might ask why the same information is entered in both programmer 'start' registers when the edit programmer might start the replay machine at 15sec before the 'start' time. Although possible such an arrangement would reduce flexibility. Firstly both programmers are identical and can be interchanged if necessary. Secondly the 'start' time in the edit programmer may be altered without altering that in the replay programmer. This changes the transition point without altering the relationship between the two tapes. Thirdly the system can be expanded to include more than one replay machine and programmer. In this case separate replay programmer 'start' times determine which machine starts and when.

The BBC Time Code Editing installation also includes the option of an auxiliary programmer associated with the edit machine. This has 'start' and 'stop' registers and allows 'staggering' of the edit by assigning the vision edit (say) to the main programmer and sound edit to the auxiliary. Simultaneous vision and sound, vision or sound only use only the main programmer with auxiliary 'off'. Less critical staggered edits can be made by manual operation of the sound record circuit.

A block diagram of the system is shown in Fig. 2.

3.1.3 External operations during editing

Times stored in all the various registers and those in four proposed coincidence detectors can be used for starting sound machines, other VTRs not equipped with programmers, video disc or any devices properly interfaced with the existing remote start facilities. The flexibility begins to multiply rapidly with introduction of further equipment.

Vision mixing facilities are also installed and of course require a minimum of two replay machines to mix pre-recorded material. As yet only one machine (which is used for replaying) is equipped with a programmer; the second is started either manually or by one of the other programmers which may in turn use either edit or replay time code. This means that accuracy is only $\pm$ 2 frames and some forethought and juggling is sometimes required to arrange that the critical material is on the programmer-equipped machine.

A second Time Code editing complex is to include automatic vision mixing. This has a time-code-initiated mix/wipe with manually pre-set rate and provides:

(*a*) repeatably exact mixes

(*b*) simplification of simultaneous vision and sound mixes.

Provision is also to be made for later inclusion of a second replay programmer.

The table summarises the degrees of accuracy with which the various editing techniques, mentioned in the preceding pages, can determine the last frame replayed, and the first frame recorded, on both 'in' and 'out' edits.

3.2 Other Applications of Time Code

3.2.1 Logging

With machines recording 'time of day' precise logging may be done by anyone, anywhere with an accurate (preferably digital) clock. A logged time may be entered in a replay programmer and in 'search' mode the machine will be spooled and stopped at this required point. The time of day logs are useless on machines not equipped with time code apparatus and therefore all other machines (initially the replay machines of 'Editec pairs'), are being equipped with time code readers ('character generators'). These give a display in the form of figures inlaid in vision and one unit is required per machine. Already two 'pluggable' units are in much use for other operations.

3.2.2 Helical scan recordings

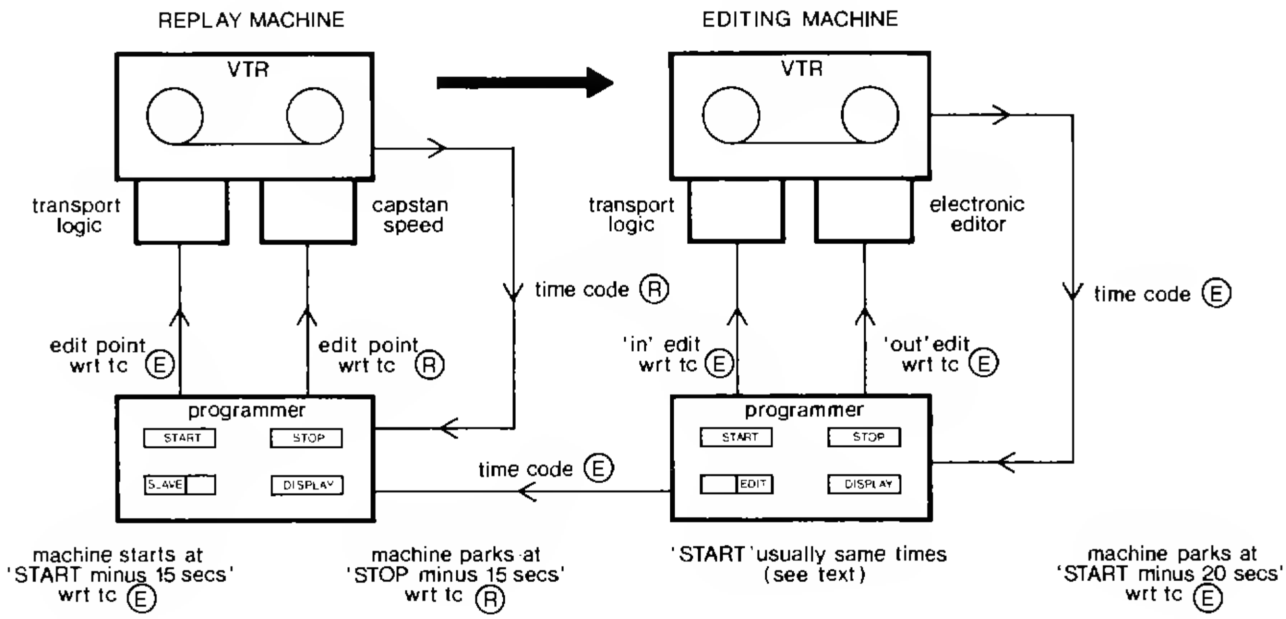
Increasingly these are made either during recording or by subsequent quadruplex-to-helical dubbing with time code display inlaid in vision on the helical recording. Detailed study and logging of these recordings can be made and the information brought to an editing session can considerably speed-up the rate of work.

3.2.3 Sound dubbing

For adding large amounts of additional sound material to an edited programme post-edit sound dubbing is usually employed. Originally this consisted of lengthy rehearsal, dubbing in sections to another VTR, and relaying in sections using vision as syncing material, all requiring expensive time on broadcast VTRs. Presently the rehearsal is done to helical scan recordings with inlaid time code recorded from the undubbed, edited quadruplex master. If this is an 'Editec' edited programme, time code is recorded on the master tape cue track while dubbing to helical scan. The sound dubbing is done using the master tape with the time code inlaid on the vision monitoring.

Since this is the same as that which all the rehearsals have been made accurate cuing is possible and time is saved. The same time code is copied to the cue track of the intermediate sound copy and relaying on the master in sections is greatly speeded up by the use of a time code comparator. This unit displays two time codes and their algebraic difference, enabling one machine to be brought into precise synchronism with another rapidly and positively on non programmer equipped machines by manual capstan override.

A proposed sound dubbing system is for the edited master sound track and time code to be transferred to two tracks of a multi-track sound recording in addition to a helical scan recording also containing the time code on its cue track. All sound dubbing can then be done using the other sound tracks, time code being used to keep sound tape and helical scan in synchronism. A final mix track can be transferred back to the master video tape once again using the time code to keep the



note
wrt - with respect to
tc - time code

EID255/LP 5:73

Fig. 2 Time code editing block diagram

TABLE OF SYSTEM INACCURACIES

System		Inaccuracies			
Physical Splicing		Absolute Accuracy For Sound Some Inaccuracy In Vision Editing			
Electronic Editing	Manual Positioning	Operator's Skill			
		'In' Edit		'Out' Edit	
		Last Frame Replayed	First Frame Recorded	Last Frame Recorded	First Frame Replayed
	Editsure	± 2	±2	Operator's Skill	
	Editec	0	±2	See Note 1	0
	On Time	0	±2	See Note 1	0
	Full Time–Code Control	0	0	0	0

EID 271LP 6/73

NOTES

1. An 'out' edit must be preceded by an 'in' edit. Any inaccuracy in the 'in' edit is exactly repeated in the 'out' edit.
2. With the PAL system, errors of ± 1 frame do not occur.
3. With 'Editsure', 'Editec', or manual control of the electronic editor, several rehearsals may be required to achieve edits within the limiting errors shown in the table.
4. With 'On Time' edits within the intrinsic ± 2 frames error can be obtained without rehearsals if time code is used to park the replay machine.
5. With full time-code control, accurate (zero-error) edits can be obtained without rehearsals.

sound machine in synchronism. This greatly reduces broadcast VTR time and also makes possible 'track laying' during the editing stage if required.

3.2.4 Intermediate dubbing and editing on film

A technique sometimes employed is to dub video tape sequences to film recording and then use film editing facilities to edit the vision as well as mix and dub the sound. This is then re-dubbed from telecine to video tape. The monochrome vision is replaced by insert editing, vision only, from the original colour

video tape. The process is cumbersome and tedious and not to be encouraged, but it may be made more efficient if the original material has time code on the cue track. This is transferred to the optical track of the film recording and is preserved in segments during the film editing. When retransferred to video tape it can be used to define the exact segments of the original material that have been retained.

3.2.5 Foreign language dubs

Time code has been used to expedite the production of foreign-language masters. When French masters of the *Six Wives of Henry VIII* were wanted, the programmes were dubbed to film recording with their time code copied on the optical track while a 'sepmag' of the English sound was made as a guide track. The French organisation used full film dubbing facilities for 'looping' carefully-timed and prepared translated dialogue, building up a French master 'mag track'. The completed track could be checked against the film recording and then both returned to the BBC. Using time code the untouched film and mag track were run in sync with the original master to produce a French-language master tape. Using this technique no VTR capability is required of an organisation specialising in the complex art of preparing foreign-language sound tracks that endeavour to marry up durations of lip movements.

Carefully-applied time code can be used in conjunction with film recording to solve many problems in sound and vision that arise when handling material received from outside sources. This is particularly so when old and/or non-standard speed films and sound dubbing are both involved.

3.3 Sundry Problems

3.3.1 Breakthrough

Initially trouble was experienced with breakthrough on some machines between cue track and sound track due to the high distribution level required for the time code (approx. + 6 dB), but modifications solved this problem.

3.3.2 Reading when spooling

The machines must be equipped with wide-band cue track replay amplifiers if they are to produce a usable output during fast spooling rates of up to 300 i.p.s.

3.3.3 Inclusion of all picture sources

Time code represents a conversion problem in that to make full use of it all likely sources on different reference sync-pulse chains (regions, Outside Broadcasts, etc.) should be equipped with generators to avoid post-recording of time code. Readers must be provided to make use of the code and avoid perpetuating two logging systems.

3.3.4 Discrepancy between mixer and electronic-editor cuts

The inability to edit at the same point as a camera cut is beginning to be annoying as the accuracy of editing increases. This problem arises because BBC vision mixers cut in field blanking preceding field one and video tape electronic editors on 625 lines edit in field blanking preceding field two. Thus one must lose at least half a frame on each side of two camera cuts when editing different takes together. As the tapes may only be shifted relatively by two-frame increments this can give rise to unacceptable music edits. Normally a half frame of one or other unrequired shot must be left in to make the music edit work, and the vision cut is only 'dirty' to the trained eye. (The video disc is invaluable in discovering exactly what is happening on these occasions.) The problem is made worse in that these cuts can only be detected after the edit is made because the monitor 'bumps' during the rehearsal or take, making it impossible to see the 'rogue' field. The bumping is caused by:

(*a*) The switch in the machine electronics (taking place at radio frequencies) being demodulated as a spurious signal.

(*b*) The over-sensitivity of the decoders and monitors used.

(*c*) inability to feed the monitor with external syncs since vision is delayed 9·5 μsec with respect to reference sync. This is due to requirements for electronic editing. (It is hoped to experiment with the use of external syncs delayed by 9·5 μsec for feeding the monitor).

3.3.5 Films with frames cut out

Problems have arisen with transfers to film recording in that on occasions when the vision should remain 'inviolate' for future resynchronising it has been tampered with making subsequent redubbing etc. difficult

3.3.6 Spool inertia

When time code editing with the replay machine near the end of a 90-minute tape (when the take-up spool is nearly full) the starting acceleration of the tape was often not great enough so that the synchroniser was 1 sec out. This of course caused the replay machine to reframe after 'sync' was achieved and gave a rehearsal or edit in error by 24 or 26 frames. This has been overcome by a modification to the synchroniser logic. On 25 f.p.s. the error detection logic was asymmetrical and gave greater range on the 'ahead' than the 'behind' portion of its 1 sec range. As the replay tape is virtually always 'behind' and only 'ahead' due to overshoot the proportions were reversed. The 5 frames gained was sufficient to overcome the problem. Reliability was further increased by removal of an inbuilt 3-frame delay before starting the replay machine, a total of 8 frames gained.

3.3.7 Erasure of programmer information

Entering information in the programmer registers erases previous information. However, plans are in hand to provide print-out of all times that one might wish to recall.

3.3.8 Ergonomic shortcomings

The ergonomics of the equipment is poor and this makes it difficult for an operator's handling of the controls to become automatic. When sufficient experience is accumulated it should be possible to design our own, custom-tailored time code editing equipment.

3.3.9 Complexity

The very great flexibility of a full-scale time code editing suite tends to result in the complexity of work being expanded rather than the same work done in less time. This is not wrong when the facilities are used creatively to achieve results that could not be realised more realistically in other ways or places but as in all stages of television production the crux of efficient video tape editing is good planning. Ever-widening options coupled with unresolved production requirements demand an excessively high decision-making rate from the video tape editor if reasonable quantity as well as quality of output is to be maintained.

3.4 Advantages of Time Code

Time code provides a 'tagging' or addressing of programme information that is fixed in relation to the recorded material and unambiguous. This allows remote logging and decision making, precise duration calculations and exact programme timings to be made.

3.4.1 Accuracy of both edit points

The accuracy of selection of the required point to join the replay material can now be made to the same standard as that to which the edit is made and is also achieved at the first rehearsal.

3.4.2 Repeatability

The repeatability of rehearsal and edit are of very great advantage. Sound work can be very exactly and rapidly repeated, altered or extended during editing.

3.4.3 Reliable synchronisation

The ability to run two VTRs in reliable sync, not only for post sound dubbing but also during editing means that mixes can be 'picked up' at the end of long sequences without the need for long-winded redubbing or unreliable synchronous run-ups.

3.4.4 No physical marking of tape

In an endeavour to achieve repeatability, 'random run-up' editing requires physical marking of the tape with 'chinagraph'. The elimination of this requirement increases the likelihood of a tape being reusable.

3.4.5 Emphasis on programme requirements

With automatic recuing, the chosen edit points (not necessarily those which prove artistically satisfactory) can be achieved without 'trial' rehearsals, and centralised control of the whole editing process becomes more civilised. The operational requirements while being more complex are shifted to the programming stage of the operation and allow more concentration and attention on the editing of the programme material.

3.5 'Ediplace'

In development is an application of time code to improve operation in editing pairs. These channels have two machines, are equipped with Editec, and can be operated by one man as either a record pair or an edit pair.

During editing considerable tedium is involved in constantly recuing two VTRs and a sound machine. With Ediplace the 'in' point on the replay machines will be chosen by entering the time code address in a register. The machine will automatically rewind and park itself 13sec earlier. The editing machine will be parked manually 10sec before the edit point as at present. After starting the replay machine the edit machine will be started at a time of 10sec 00 frames earlier than the chosen point in the register. This reduces the 'parking variables' to one, makes marking of the replay tape unnecessary and speeds up recuing. There will be a facility to adjust the stored 'in point' time by plus or minus a number of frames.

4 Use of Video Disc in Editing

The facility of slow motion (forward or reverse), freeze and (with certain limitations) up to double-speed replay from the video disc make it a powerful addition to video tape editing capabilities. The BBC Video Disc control logic has been extended in such a way that it can be operated by external command signals. These are distributed by the local remote control facilities system. With Editec this means starting the disc at any pre-selected speed by commands originating at either cue read-off or edit-point time. Start time can be varied over a range of up to 10sec by a variable delay incorporated in these modifications.

A time-code editing channel can, by nature of its equipment, originate commands through the remote control system at any time, independently of edit points.

A second development of the BBC video disc is a 'field counter'. The fields recorded can now be precisely selected and the video disc can always be recued accurately to any one of the 1800 fields (36sec at normal speed) recorded. These features mean that the disc can match the accuracy of time code, making possible repeatably precise tape/disc edits. The facility to make subsequent changes in the disc operational mode is now under development. These commands may be originated from an editing channel or the field counter itself to reverse or freeze.

The channel also has a black edge caption facility which might be extended from its present manual 'cut in', 'cut out' operation to external control as above.

Imaginative use of the video disc and facilities allied with mixing during video tape editing allows a wide range of effects and sequences to be achieved.

5 Future Possibilities

As stated earlier the 'continuous information' aspect of time code gives rise to many benefits and may be expected to give rise to more in the future.

Already centralised time-of-day code can be used to start programme transmissions precisely. In the United States time code is used to control programme junctions with automatic slide changing, mixing, overlay, TK & VT running etc., to

create complex presentations far too involved for manual, real-time operation.

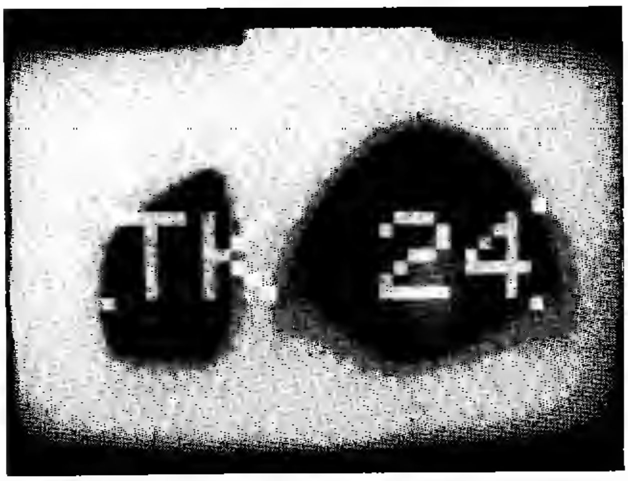
Systems available now dispense with pre-wired programmers and fixed options by using computer control of equipment to instructions given by keyboard and light pen on a visual display unit. The computer editing programmes are on computer tape, thus extending operations means only playing-in an extended programme. The unit can ask for decisions and point out errors as required. Additionally all edit decisions made can be stored and recalled. This at present is the limit of 'on-line' editing.

'Off line' editing involves making programme decisions using low-cost equipment such as helical scan machines or monochrome 'disc packs'. The decisions made are stored on punched paper or magnetic tape that is used later to control assembly of the programme on broadcast VTRs. This moves the decision making time off broadcast VTR channels. The disadvantages of having to pre-load these units with material, the obvious need to rehearse or simulate completely the intended edit coupled with the great flexibility to which producers are accustomed (particularly with respect to sound track editing) give rise to much duplication of effort and equipment. They are perhaps more suited to short, intensively-edited sequences, such as titles, special effects, and commercials.

Video tape editing can be seen to be reaching a stage where production requirements are no longer restrained by equipment capabilities but by equipment capital cost. Limitations are no longer intrinsic in the medium; only in the cost of the time which it is realistic to expend on a programme.

The development of ever-improving small, light, high quality cameras, recorders and less expensive format machines promises to widen the horizons of electronic programme production. It seems likely that video tape editing in the BBC will evolve further in the mixture of 'on' and 'off' line techniques that has already begun. This suits the nature of our requirements and makes possible many specialised services and flexible combinations of these to master the occasional 'unique problem' programmes.

Inevitably video tape must cease to be regarded only as a technical production facility and come to be considered a creative medium.



Off-tube picture of source-identification information added to the output of a stationary telecine machine

Picture-Source Identification Unit UN1/684

In operational areas of the Television Service where programme staff have available a number of displayed pictures with little visible difference, there is a need for a means of identifying the sources from which the various picture-signals are being received.

The source-identification insertion-unit provides such an indication for the signal from a telecine or video tape machine. It accepts the output signal from the machine and, until the machine is started, adds to this signal one which superimposes on the displayed picture a peak-white alphanumeric identification of up to five characters (e.g., TK24, VT17, etc.). Also included in the display are four corner dots which flash synchronously with keyed tone if this is used to identify the audio line.

The dots forming the displayed identification are eight line-widths square, and the position of each in the picture-area is determined by the insertion of a diode on a matrix. The diodes are permanently connected, and therefore the unit is usable only with the particular machine for which it generates the identifying signal; a separate unit must be provided for each such machine.

When the machine is run, the identification is automatically removed from the output signal, to ensure that it shall not be transmitted inadvertently.

The unit is constructed on a chassis forming a plug-in module in a BBC $5\frac{1}{4}$ in (133 mm) general-purpose (bay-mounting) panel. It occupies 108 mm of panel width. Supplies of mixed synchronising-pulses (or composite video signal) and a.c. mains are required.

Saturday Sport on BBC Television

D. M. W. McGregor and D. J. Fawcitt
Assistant (Operations), Television Studios — Video Tape Operations Manager, Television Recording

Contents

1 Introduction

On Saturdays the enthusiast has between five and six hours of sport viewing available on BBC-1. The three regular programmes are *Grandstand, Today's Sport* and *Match of the Day*. BBC-2 has its own 55-minute programme, *Rugby Special* showing the highlights of two rugby matches. *Grandstand*, which starts at about 12.30 and finishes shortly after 17.00, includes many of the sporting events that are held both nationally and internationally. The various items may be live or prerecorded highlights, plus an up-to-the-minute result and news service. *Today's Sport* is a 5-min round-up of sports news and results and follows the evening news bulletin at 17.45. *Match of the Day* usually features recorded highlights of two of the day's top football matches and lasts for about an hour, starting around 22.00. The control centre for these three programmes is Studio E at Lime Grove,* and the linking announcements and discussions are broadcast live from this studio, so that Saturday is always a busy day for both the production staff and the engineering staff. The content of the programmes, the facilities required and the transmission times vary from week to week, but the basic studio operation is similar.

2 Studio Operation

2.1 'Grandstand'

The day begins when the engineers and the Technical Operations Crew arrive for duty at 09.00. While the studio is being lit the camera crew connect the camera cables and rig the studio monitors and teleprinters. The Sound Crew start rigging the studio microphones and the other sound equipment required, including Direct Exchange Telephones, PABX extensions, talkback to the Production Control Room, Control Lines from Exchange Telegraph for racing starting prices, and headphone feeds for programme etc. The outlets for the various facilities appear on trunking which fits into the front of the desks occupied by the sports sub-editors and their staff and is connected to the appropriate outlets on the studio walls by means of multi-conductor 'hose-pipe' cables. The studio engineers commence lining-up the cameras and the vision mixing equipment etc.

Because of the wide range of sports and venues, the problem of ensuring that the correct number and type of temporary and permanent circuits are provided between the remote sources and the studio is a major task. Information regarding the use of the circuits within West London Television premises is issued daily in a Lines Booking Sheet.

The circuits from remote sources arrive in the studio via the Combined Vision Apparatus Room (CVAR) and the engineers there start the day by checking the Lines Booking Sheet to ascertain what outside broadcasts are to be involved in the day's operation, and what lines are to be used to provide the various facilities that are going to be required. Some of these outside broadcasts will be transmitted live, and others will be required for preview purposes only, as they are to be recorded on video tape which will be edited and replayed at some time after the event. They also need to learn what method of synchronisation is to be used for the various remote sources, including Television outside broadcasts, video disc and the five or six videotape machines, which are fed from Television Centre. There may be inserts from overseas, which come via the International Control Room and possibly Standards Convertors, both of which are also situated at Television Centre. The methods of synchronisation available are Natlock/Slavelock, Natlock/Genlock, a commercial Fast Genlock system or FS2, the BBC Field Store Convertor, working in a 625 PAL–625 PAL mode. It sometimes happens that a combination of several of these systems is employed and this entails careful planning with Television Outside Broadcasts Department and Television Recording Department.

It is important that the editor Alan Hart, and the Studio Producer Brian Venner have constant communication with Frank Bough, the linkman, who is seen and heard on transmission, and a system has been developed to provide this facility wherever Frank Bough is in the studio. The deaf-aid that he wears carries Production talkback so that the pro-

* Lime Grove and the Television Centre in Wood Lane are the two studio centres in the West London Television premises complex.

ducer can speak to him at all times. Should the editor wish to talk to him he may do so by means of the talkback microphone or by using a special telephone, the microphone of which is also connected to the deaf-aid. The telephone ear-piece is fed with a pre-hear output of Frank Bough's personal microphone to enable two-way conversation to be carried out, and thus only one microphone is used for both transmission and talkback purposes. If Frank Bough wishes to contact either the Editor or the Producer he operates a push-button that he carries in his pocket and this signals the special telephone by means of a d.c. signal fed along his microphone cable.

An important source of information for general and sports news during the day is the bank of Teleprinters on the studio floor. A Communications Department teleprinter technician arrives at about 10.00 to check that the ten teleprinters that are used (including the inshot teleprinter used for football results) are all functioning correctly and that the required services are connected to them. The services used include:

Press Association A – general news headlines
Press Association B – detailed general news
Press Association C – sports news
Reuter UK – general UK news
Reuter 2 – sports news
Exchange Telegraph Sport 1
Exchange Telegraph Sport 2

By 10.30 the Editor and the Studio Producer will have arrived in the studio along with the Producer's secretary, sub-editors, caption artists, Teleprinter attendants and messengers etc., and will start the studio camera rehearsal. This includes linking announcement positions, caption positions, overlay shots and checking the time and cues into and between telecine and videotape items.

From 10.30 until 11.30 the Television outside broadcast circuits start to arrive in CVAR and are passed on to the Technical Manager after the signal parameters have been checked. The Natlock circuits are tested and equalised and Natlock/Slavelock error signals are sent to the various Television outside broadcasts, which are to be used synchronously during the programme. By 11.30 the local camera rehearsals are completed and the outside broadcasts sequences are rehearsed, particularly if they feature in the opening titles. At 11.45 the studio rehearsal ends and the cameras are lined-up, remote sources are checked for synchronisation and telecine and videotape areas prepare for transmission. By 12.30 everything is checked and *Grandstand* is on transmission.

2.2 'Today's Sport'

At 17.05 there is time for a rapid check line-up with the remote sources involved in *Today's Sport*. Captions are up-dated, late results are added and checked on cameras, linking announcement camera shots are checked and there is a quick camera rehearsal. At 17.45 *Today's Sport* follows the evening news bulletin and weather forecast and by 17.50 the afternoon commitment is finished and the Technical Crew are off duty.

2.3 'Match of the Day' (MOTD)

Another Technical Crew arrive in the studio after dinner and from 19.00 to 20.00 the studio is reset and relit for *Match of the Day*. The Editor, Sam Leitch and the Studio Producer, Jonathan Martin will have spent the afternoon in Sub Control Room at Television Centre watching two or occasionally three football matches simultaneously and will have left the Sports Production Assistants in charge of editing the VT material to be used later that evening while they return to the studio.

At 20.00 there is a camera rehearsal for the opening and closing sequences of the programme, linking announcements into the videotape inserts plus numerous captions particularly if 'Goal of the Month' is being featured. From 20.45 to 21.10 a check is carried out with the videotape area at Television Centre and Network Control 1, in order that last-minute changes and alterations to the script can be checked and rehearsed.

Shortly after 22.00 Studio E is back on transmission for about 60 min with all the excitement of some of the best football matches which have taken place during the afternoon.

3 Video Tape Operation

The studio and Outside Broadcast facilities are extremely sophisticated and flexible, but it would be impossible to produce a balanced show of the present style by relying on live material alone. Two telecine machines are always available to replay film inserts into *Grandstand* but the preparation of film – planning, shooting and editing – is a comparatively long process and, topicality being all important, the time factor imposes its own limitations.

Since video tape recording facilities were first introduced to the BBC in 1958, Sports Department, more than any other television production group, have made use of the versatility of video tape machines and stretched the equipment and operational staff to the limits of their capability. Sport, in the video tape sense, can be split up into three broad categories.

Firstly the preparation of material before the transmission which may take the form of a brief history of a personality, team or event. This may end up as only a few minutes of programme time, but it can take many hours to prepare because of the large number of tapes which contain the original material and the difficulties in matching sound and vision recorded on many different occasions. Such compilations are always topical and indeed the idea is often conceived only a day or so before transmission – hence the frequent last-minute rush to complete items.

Secondly there is the material which is recorded and transmitted within the programme transmission time. It may simply be recorded to act as a delay when two items occur simultaneously at Outside Broadcasts, but it is also likely that the material will be edited into a package – as frequently happens with athletics, for example.

The third category covers the 'Match of the Day' type of programme where the only 'live' material is often the links between items, the rest of the programme being made up of edited highlights of one, two or perhaps three football matches, together with interviews, which have been recorded earlier in the day.

3.1 Afternoon Period

It is during the afternoon that the Saturday Sports load reaches its first peak. Whilst *Grandstand* is on the air, the

football matches for *Match of the Day* must be recorded as well as the two *Rugby Special* matches, and it is quite normal for twelve out of the twenty-four video tape machines in the basement of Television Centre to be in use for Sport. On special occasions, such as F.A. Cup Final Day, the number could possibly be sixteen or more – and this does not allow for recordings required by Television Enterprises!

Four or more adjacent machines, operated by engineers (including at least one VT Editing Engineer) are normally allocated to *Grandstand* itself and these machines must provide recordings of any incoming material, replays of pre-packaged and newly-recorded items as well as editing facilities if required. The afternoon's work is scheduled in advance by the Sports Production Assistants who seem to spend much of their life in the VT Area, but the keynote of this programme is flexibility and a machine may be asked to stop recording, transmit a short sequence and then revert to recording within the space of a few minutes.

It is usual for all the machines involved in such an operation to have their outputs fed to the studio via the Complex Operations Desk, a centrally-situated monitoring and switching desk which enables the Production Assistants (PAs) to control the operation and yet be in close contact with the studio destination via the built-in communication facilities.

This desk can accept up to six machines on the input and can allow the PA to select any one of those machines to be fed up the one line to the studio. Sound and vision circuits are switched simultaneously and it is possible to cut from machine to machine on air without disturbance. The desk has four 11-in. monochrome monitors which show Studio output, Switchable Preview of available VT machines. Desk output and Network output

An electronic-count-down generator is an extra facility which automatically shows a 10sec count-down on the desk output vision whenever the play button of the selected machine is operated, thus giving reassurance to the studio that the 'run cue' has been heard and at the same time ensuring consistent timing of the vital 10sec run-down.

All vision replayed from VT during *Grandstand* is expected to be fully synchronous in the Studio and this is initially achieved by Natlock/Slavelocking one of the pulse chains at Television Centre to the Lime Grove studio pulse chain. It has been found that once the generators are locked, the monochrome correction loop can be broken for long periods without the chains drifting apart. It is still necessary to make sure that each machine is accurately colour phased at the studio mixer and Digital Phase Shifters are used for this purpose. Providing each machine has been fed to the Studio Mixer input before it goes on air, its Phase Shifter will be pre-set to very nearly the correct position and any remaining errors will be quickly corrected after the machine has stabilised during its run-up for transmission.

The last part of the *Grandstand* programme is often a hectic round-up of the afternoon's proceedings and this relies largely on VT contributions. All the available machines may well be used for this within the space of a few minutes and the success of the round-up depends upon the closest possible co-operation between the VT Engineers, the Sports PAs, in the VT Area and the Studio team. With *Grandstand* off the air at 17.05 there is just time to take a deep breath before the *Today's Sport* summary programme although for this only two machines are normally required since most of the interest is in the football results from the studio.

3.2 Early Evening

Although *Grandstand* may be over, *Rugby Special* is not far off and the editing of the matches has already started in two of the 'Record Pair' cubicles. Each cubicle is equipped with two video tape machines which, during the afternoon have made a master and backing copy of one match. By 18.00 hours the machines are being used as 'edit pairs' and from the master tapes electronically-edited shortened versions are being made.

Time is short, and so the Sport's PAs and the VT Editors working in the channels have an air of concentration which they must maintain right through until transmission. The aim is to have both matches edited and ready for transmission by 19.15 but if either match has many tries or interesting incidents then the number of edits needed to cover them is also high and editing sometimes continues to within a few minutes of transmission at 19.45.

Although electronic editing is the preferred method of joining wanted sequences together it is worth mentioning that the old 'cut edit' system – where the tape is physically cut with a razor-blade and the wanted pieces joined together with a metalised splicing tape – still has its uses. In electronic editing the programme is compiled by copying the wanted sequences from one machine to another, the editing machine being specially equipped to enable it to change from replay mode to record mode without leaving a disturbance on the final tape. This means that to produce a 45 min programme by electronic editing at least 45 min of copying time must be available, and two machines will be required. There are still many situations, mainly in sports programmes, where a tape will be cut either because of the time factor or because only one machine is available for the operation. A skilled VT Editor can make a physical splice in about a minute once he has found the cutting points and it is sometimes worth splicing a valuable tape to gain the extra few minutes.

If the Rugby editing has gone well, the final transmission will come from one tape, but if one of the matches has been difficult and has taken a long time, then two machines will have to be used and a 'change-over' made on air. *Rugby Special* is a complete programme on tape, the opening, closing and any links being recorded from the Outside Broadcasts, and so it is possible to send this programme direct to Network without it going through a studio to be tidied up.

3.3 Late Evening

By the time *Rugby Special* is on the air, the MOTD editing should be well under way. Immediately after the matches any interviews with players or team managers which can be obtained will have been recorded and Sam Leitch and Jonathan Martin will have briefed their PAs in VT on how much material from each match should be used. Apart from the recordings made at Television Centre, each match has a mobile or portable video tape recorder on site and this is fed with the output of a camera situated behind the goal. This is used to give an alternative view of any shots at goal and the tapes must either be returned to Television Centre or the interesting parts played down the line to London, where

Sports Staff can decide whether to incorporate them into their programmes or not. During the match the Sports PAs will have made their own careful notes of action in the match against the elapsed VT spool time and by the time they have worked out rough cutting points the VT Editors will have copied the opening sequences of the matches.

One VT Editor will be working on each match, either by himself on a record pair or on two of the multi-purpose machines with another engineer to operate the play-in machine. Although at least four hours are available between the end of recording and the start of transmission, the whole of the time is needed to produce the smooth final product which is expected. Editors and PAs pride themselves on their ability to disguise the edits and this can be achieved only by taking great care in choosing the cutting points and then mixing the sound over the edit point to ensure a smooth transition. To help with problems that can arise from attempting to edit in the middle of commentary, a feed of 'clean effects' (crowd noise) is often fed on a separate line from the football match and recorded on the second audio track of the VT machine. During editing this can be substituted for the mixed commentary and effects of the main audio track until the unwanted commentary is finished.

4 Video Disk

The highlights of each match – goals, disputed decisions etc. – often warrant closer inspection and it is common for slow-motion replays of such incidents to be inserted into the edited version from the Video Disk Recorder (Fig. 1). Although not mentioned previously, the Video Disk has been in operation all afternoon for *Grandstand*, and during that time will have been used for replays of tries in rugby football, fall or finishes in horse racing, wickets in cricket, match points in tennis, or whatever else is considered of interest to the viewers. The machine itself is housed in a cubicle separated from the main area by a large glass window. It is within sight of the Complex Operations Desk and can be routed through the desk although this is not normally done. Once the disk is recording, it has available at any one time the last 36 sec of programme and, if the machine is switched to 'Play' that 36 sec can be stored indefinitely. Apart from replaying at normal speed, it can also switch to half speed, one-fifth speed or 'freeze', which gives a 'still frame' for as long as the position is held. There is also a 'variable' position where the replayed speed is continuously variable from 'freeze' to normal speed and this is the most commonly-used position for showing the action replay of a goal.

The video disk is often used 'live' on sports programmes and for this it is used via a 'Hot Switch'. This simply means that the Outside Broadcast and the Video Disk are both fed to the input of a switch and the Disk Operator, who also has a record feed of the O.B., has control of the switch so that he can

Fig. 1 Video disk motor unit showing tracking mechanisms

either feed the O.B. to the destination or switch the disk output (in the replay mode) to line when so directed.

The Video Disk room also has a caption scanner installed and, apart from using this to superimpose the 'BBC Action Replay' caption on the video disk inserts, it can be used as a separate facility to add titles to an otherwise complete programme.

For MOTD the interesting incidents have to be played from the video tape on to the video disk and then transferred back at the best speed to show the action – not in itself a long job, but there could be up to fifteen such operations wanted during the evening and they can take up a large part of the editing time.

5 Final Activities

By 21.30 the studio will be hoping to start rehearsals with VT and the opening titles at least will be ready on one machine. As with Rugby matches, if incidents in the match are few, then the editing will be completed in good time and probably ready for the start of rehearsal. It is quite common, though, for only one of the matches to be completed by transmission time and the other must be completed during the first half of the programme. The Complex Operation Desk is again used to route machines to the studio and as the second match is switched to line then the engineers, editors and production staff noticeably relax and start clearing up the many tapes which are lying around, completing the paperwork and discussing problems met during the day.

The studio cannot start clearing up until the closing titles are complete, but these final minutes of the day bring a last burst of activity as the crew de-rig the technical equipment and return it to stores, and the Studio Engineers turn off equipment which does not need to be continuously powered.

Another six or seven hours of Sport on Saturday is over and a total audience of perhaps 18 million people will have watched some or all of it.

Predicting Faults in Mechanical Structures and Other Systems

An invention by the late Mr Geoffrey Gouriet is the subject of a provisional patent specification.* This invention is concerned with detecting the occurrence of a fault in a system, for example, a mechanical structure such as a mast, where a fault could lead to its collapse.

Masts such as are used to support broadcasting aerial systems are in a continuous state of motion due to the effect of wind. If the motion of a point at, say, the top of the mast is resolved into two orthogonal components along horizontal axes, the displacement of the point along either of these two axes can be regarded as the response of a linear system to a random excitation, the effects of non-linearity caused by turbulence being ignored. Experiments have shown that the fluctuating forces caused by wind closely resemble random phenomena with a Gaussian probability distribution.

Because of mechanical constraints, imposed by the distributed mass and compliance of the mast structure, the frequency spectrum of the displacement will be substantially confined to a narrow band outside which little energy will exist. Typically the oscillatory movement of a tall mast may have a period of about 10 sec, so that the spectral energy of the random displacement will principally be confined to a bandwidth of about 0·1 Hz and will be approximately uniform over this bandwidth.

Where a signal has a limited bandwidth it is theoretically possible to predict future behaviour of the system with a certain likelihood of error. This is because a complete surprise in the behaviour can only take place if there is no indication whatever of the event before it happens, and this requires an infinite bandwidth. The amount of time ahead that it is possible to predict depends upon how fast the signal to be predicted is varying and this in turn depends upon its bandwidth. The maximum prediction time for a given statistical error is proportional to the reciprocal of the bandwidth, and is also dependent upon the rate of cut-off, i.e. the rate at which the spectral energy of the signal vanishes beyond a fixed upper-frequency limit.

In accordance with this invention it is proposed to detect the occurrence of a change in the structure of a system having a finite frequency response by analysing the behaviour of the system in response to a stimulus, to predict the future behaviour of the system therefrom, and to detect any relatively sharp changes in the predicted response corresponding to changes such as faults occurring in the system.

Where the analysis takes place by sampling the signal, it is necessary for the sampling frequency to be at least twice the cut-off frequency.

In Fig. 1 the actual response of a system is shown at A. In the case of the mast described above this response is the acceleration of the top of the mast along one of the orthogonal horizontal axes. Acceleration is relatively easy to measure by mounting an accelerometer at the top of the mast, but velocity or displacement would do just as well. It is assumed that a fault due, say, to metal fatigue occurs at time t_1, and the actual acceleration that would have been measured in the absence of the fault is shown in the dashed line A^1.

The predicted acceleration B precedes the actual acceleration A by a lead time T, and resembles the actual acceleration to a predetermined accuracy which as noted above depends on the relation of the lead time T to the system cut-off frequency. At time t_1–T the curve B is predicting the point on curve A at which the fault occurred. Between the times t_1–T and t_1 the curve B will predict the response that the system would have had if the fault did not take place, and thus continues to predict curve A^1. It cannot predict curve A between these times because there is no information available as to what will be the response of the system after the fault has occurred. After time t_1 such information does become available and the predicted acceleration B quickly responds to the new behaviour characteristics and tends to predict curve A.

* No. 35953/72: Improvements in Fault Detectors.

Curve B will thus jump at time t_1 between the value of curve at time $t_1 + T$ and the value of curve A at time $t_1 + T$. This step in curve B is used to provide an indication of the fact that a change (i.e. fault) has occurred in the system.

The change in the value of the predicted signal will be abrupt and will give rise to a momentary increase in bandwidth, provided the fault takes effect in a period of time which is short compared with the lead time T.

Fig. 2 is a block diagram of a detector for detecting faults in a system and using the principles described with reference to Fig. 1. To an input 10 is applied a signal indicating the response of the system to a stimulus, in the present instance the acceleration of the top of an aerial mast. A predictor 12 predicts the value of the signal T seconds ahead of the input signal. A differentiator 14 is connected to the output of the predictor 12 and detects the slope of the predicted information and thus will produce a peak in its output when the predicted signal changes abruptly as described above. This peak is detected by a peak detector 16 which in turn actuates an alarm 18 of a type appropriate to the system concerned.

The peak detector 16 could be replaced by a high-pass filter, since the bandwidth of the predicted signal will in the absence of a fault be virtually the same as that of the actual signal. If the characteristics of the system were to change suddenly, even slightly, the consequent abrupt change in the predicted signal would result in a momentary increase in bandwidth, and this would be detected by the high-pass filter.

The apparatus could be used with a device monitoring the temperature of a machine, for example an aero-engine. In

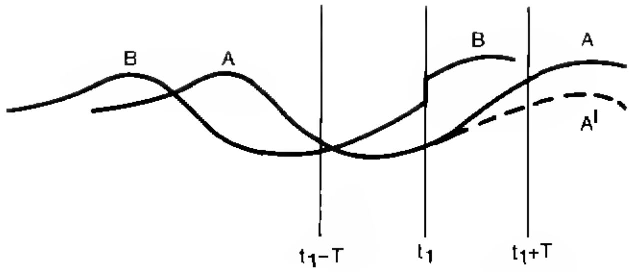


Fig. 1 Actual and predicted response of a system when a fault occurs.

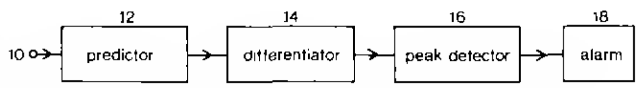


Fig. 2 Block diagram of a fault detector embodying the invention

normal circumstances, due to thermal inertia, the bandwidth of an electrical signal varying in proportion to the engine temperature would be very restricted and the future value of temperature could be predicted with little error for a relatively long lead-time. If, however, a fault were to develop suddenly which would cause the temperature to rise above the predicted value during a period of time equal to the lead time, then the value of the predicted signal would suddenly change to a new value and this sudden change would be detected by the detector. Other similar applications will be apparent.

UHF Coverage in Remote and Mountainous Areas of the United Kingdom

W. Wharton, C.Eng., F.I.E.E.
Head of Transmitter Capital Projects Department

Contents

1 Introduction

In the early 1960s a basic plan for four-programme u.h.f. colour television coverage of the United Kingdom by sixty-four main stations and approximately 450 relay stations was prepared.* Within the framework of this plan, the stations have been built progressively and their coverage surveyed. The surveys have enabled the service areas of the main stations and of the larger relay stations to be determined and it has been found that the number of main stations can be reduced to fifty-one and the number of relay stations to about 400. The reduction in number of stations is possible because the service areas of some stations have been found to be greater than was predicted. Further, methods of prediction of u.h.f. coverage have become more accurate and it is therefore possible to plan the coverage provided by the relay stations more economically.

A u.h.f. coverage of over 90 per cent of the population of the United Kingdom has now been achieved and attention is being concentrated on the planning of the transmitting stations required to serve the more remote areas. When the basic plan was drawn up it was realised that it would not be economically possible to provide complete coverage of the small scattered pockets of population in the mountainous and remote areas of the United Kingdom by main stations. This prediction has been confirmed and it has been established that the coverage of each of these areas can only be achieved by a network of relay stations for which an 'area plan' must be prepared giving an outline of the number, type and location of the relay stations required. The formulation of an area plan and the subsequent detailed technical planning, site acquisition and station construction requires a total period of about five years. It will be seen, therefore, that u.h.f. planning and station construction in remote areas is a complex matter and, in this paper, an attempt is made to summarise and explain the many factors that must be borne in mind and the difficulties that are encountered.

The construction of the stations now comprising the basic plan (fifty-one main stations and approximately 400 relay stations) will be completed by 1980 and will give a coverage approaching 98 per cent of the population of the United Kingdom. Further work aimed at reaching a coverage of the United Kingdom as near to 100 per cent as is practicable will then follow and will require the building of relay stations to cover the small pockets of population left unserved in the current plan. Many of these pockets will be in remote and mountainous areas and the development of new types of easily installed and maintained equipment is being studied. However, the number of additional stations required cannot be determined accurately until the basic plan is nearer completion and the remaining gaps in coverage can be clearly identified.

* Main stations have a transmitter power of 5kW or more and provide the basic coverage of the United Kingdom. Relay stations are fed by radio pick-up and have transmitter powers in the range 1W to 1kW. All stations are designed for the radiation of four programmes (BBC-1, BBC-2, IBA and a fourth service as yet unallocated).

2 Planning Problems

2.1 Site Acquisition

The rate at which u.h.f. coverage can be extended depends basically on the rate at which sites can be acquired. But the acquisition of sites is a lengthy process involving technical, legal and administrative problems and, before it can commence, it is necessary to carry out predictions of coverage to establish the approximate location of each station. There is usually more than one location from which the required area could be served and it is necessary to establish the approximate location that will require the minimum transmitter power and the simplest possible transmitting aerial. A further complication is that relay stations are normally fed by radio pick-up of a main station or of another relay station. The site location must therefore be chosen so that an adequate signal is available. Once the optimum area for the location of

a station has been decided a search for a suitable site or sites is made, bearing in mind the need for reasonable access, the need for an electricity supply and the possibility of legal or local planning objections. Once a possible site has been identified, technical tests are carried out to confirm its suitability and outline planning permission is applied for from the Local Authority. When this has been obtained the legal steps necessary to buy or lease the site can be initiated.

The site acquisition procedure and the associated technical planning work occupies an average of about twenty months and, if undue difficulty is experienced in obtaining planning permission or persuading the landowner to sell or lease the site the period can be much longer. Difficulties in obtaining planning permission are particularly likely to arise in remote and mountainous areas which are often in national parks and are subject to particularly stringent planning standards. It is not unusual for planning permission for a station to be dependent on the provision of a new type of mast and special type of building designed to harmonise with the landscape.

2.2 Access

The nature of u.h.f. propagation is such that effective coverage can only be obtained if the transmitting stations are sited on high ground. As a result, in remote or mountainous areas, transmitting sites have often to be located at some distance from the nearest metalled road and the cost of the access track is necessarily high. At sites situated some distance from the nearest road it may be possible in the future to dispense with an access track suitable for wheeled transport and, instead, to use tracked vehicles capable of traversing open country. However, the advantages of this approach to the problem are not as great as might be thought, as the absence of an access track may considerably increase the cost of building the station. The building contractor will need to provide special vehicles to transport his men and material to site and, when a large building is required, the added cost may well eliminate the savings resulting from the elimination of the access track. Nevertheless, advancing technology is making it possible to provide all-solid-state equipment at the lower power relay stations with a consequent increase in reliability and a reduction in size of the building. At these stations the use of tracked vehicles may, in some cases, prove financially advantageous.

2.3 Programme Feed Problems

To provide a separate video cable or radio link feed to each of the large number of transmitting stations required in the u.h.f. coverage plan would be prohibitively expensive. The main stations, which are required to 'opt-out' and provide local programmes are, in general, provided with a video programme feed, either by the Post Office or via a BBC radio link. But at all other stations every effort is made to provide the programme feed by radio pick-up of another u.h.f. transmitting station. In mountainous areas particularly, however, this is often impossible, as the population is scattered in small pockets so widely separated that it is impossible to receive a usable signal from any other u.h.f. transmitting station. In such cases, it is necessary to provide a radio link connecting the relay station to the nearest point at which a signal is available. As a result, in addition to the transmitting site, a separate receiving site must be provided and the capital cost of the station is significantly increased.

2.4 Station Reliability

All u.h.f. transmitting stations are designed for unattended operation and the transmitting equipment must therefore have high reliability. The BBC policy is to provide automatically-switched reserve transmitting equipment, which enables the service to be maintained at one-quarter of the normal power when the main equipment is faulty. This reduced level of power provides a service which is acceptable, provided that the repair of the fault can be completed in a day or so. However, sites in remote areas may be inaccessible for up to two weeks during severe winter weather conditions and in such cases it is necessary to make a careful assessment of the loss of service which will occur when the reserve equipment is being used. If a significant number of viewers will lose their service it may be necessary to provide a full power reserve transmitter with a consequent increase in equipment and building costs.

An important factor which must be taken into account in assessing the standard of service provided is the reliability of the electricity supply. In remote areas the supply is often carried on a poled route and is therefore liable to prolonged breakdown during severe weather conditions. It may therefore be necessary to consider the provision of an automatically-started diesel-alternator to maintain the services in the event of mains failure. The provision of a diesel-alternator will increase the capital cost of the station and, to facilitate deliveries of diesel oil, the provision of an improved access track may be necessary resulting in a further increase in capital cost.

2.5 Frequency Allocations

The number of channels available in the u.h.f. Bands IV and V is limited and the coverage plan for the United Kingdom is therefore based on an extensive use of common-channel operation. In many areas, common-channel operation can be accommodated without difficulty but, under certain topographical conditions, it can impose severe planning restrictions. The propagation of u.h.f. signals is 'semi-optical' and thus there is usually no difficulty in allocating channels to serve small communities living in valleys shielded from common-channel transmissions. On the other hand, areas where the terrain is flat may be exposed to common-channel interference from a number of u.h.f. transmitting stations. Under these conditions, the allocation of interference-free channels becomes difficult, and a carefully interlocking frequency plan must be worked out for the area.

2.6 Costs

In terms of cost per viewer, it is inevitable that the expenditure on u.h.f. coverage of small pockets of the population is well above the average. Small relay stations in the populated areas of the United Kingdom serve an average of about 6000 people but, in remote areas, the average will be little more than 1000 and the higher construction costs increase the cost still further. In the remote and difficult areas of mid-Wales and Scotland,

the cost per viewer is ten to twenty times that obtaining in the more densely-populated areas of the United Kingdom.

3 Coverage in Scotland and Wales

Section 2 of this article outlines the problems arising in the planning and construction of u.h.f. transmitting stations in remote and mountainous areas. In this section a brief description is given of the particular problems encountered in planning u.h.f. coverage in the difficult areas of Scotland and Wales.

3.1 Scotland

The coverage of the northern and western areas of Scotland (including the Western Isles) poses one of the most difficult problems encountered in u.h.f. planning. Much of the terrain is mountainous with a population located in a number of scattered pockets. The mountainous terrain results in a need for long access tracks over difficult country and also makes it impossible in many cases to feed a relay station by direct radio pick-up from its neighbour.

Fig. 1 shows the locations of the main u.h.f. transmitting stations which provide the basic coverage of Scotland, and outlines the plan for the coverage of the more remote areas. The plan is based on the provision of three 'spines', each of which comprises a series of transmitting stations fed by radio links or, where possible, by direct radio reception. The main stations supplemented by the three spines will provide a network whereby coverage can be progressively extended to cover unserved pockets of population.

3.1.1 The Spine feeding Argyll

The coverage of the western area of Scotland will be based on the Argyll transmitting station, which will be sited either on the Isle of Mull or at the existing BBC v.h.f. transmitting site at Oban.

A site on Mull is preferred as it will provide the maximum population coverage and enable a total of 11 500 people to be served. The bulk of these people live in Oban but the remainder are widely scattered in the Argyll area. An additional advantage is that a relay station serving about 4000 people in Fort William could be fed by direct radio pick-up of the Mull station.

If a suitable site on Mull cannot be obtained, it will be necessary to use the existing Oban site where a u.h.f. station would serve approximately 8500 people. To approach the coverage of Mull it would be necessary to build three additional small relay stations, but even then about 800 widely scattered people who would be covered from Mull would remain unserved.

It will not be possible at Mull or Oban to provide a programme feed by direct radio pick-up. In the case of Mull, the programme feed would be provided by radio pick-up of Black Hill in the South Knapdale area followed by a one-hop radio link. In the case of Oban, direct radio pick-up of Black Hill at South Knapdale would also be used but a two-hop radio link would be required, necessitating the acquisition of an additional radio link site. Further, the proposed Fort William station could not be fed by direct radio pick-up of the Oban station and an additional radio link would therefore be required.

3.1.2 The Spine feeding Lewis

The Lewis main station will serve 15000 people on the island of Lewis and will eventually act as a 'lighthouse' feeding a number of relay stations in the Hebrides. A number of sites for the Lewis station were considered and the final choice was dictated by the need to provide the required service at the minimum capital cost. The site which has been selected requires a relatively high mast height of 500 ft but has reasonably good access and minimises the number of relay stations that will eventually be needed to serve the Hebrides.

Lewis is remote from all the other Scottish u.h.f. transmitting stations and studies have shown that the most practical and economic method of providing a programme feed is by a radio link from the Rosemarkie station which is situated about 100 miles to the east. The route will follow an existing 405-line radio link feed but two additional repeater points and two additional passive reflector points will be required. The building season on Lewis is of limited duration and there is a lack of local skilled labour and of building facilities and, in order to build the station as economically as possible, it is planned to carry out the work in three phases. The access road will be constructed in the late summer of 1973, the buildings will be constructed during the summer of 1974 and the transmitting equipment will be installed during 1975.

3.1.3 The Spine feeding Orkney and Shetland

The Orkney and Shetland stations will be the most remote of all the BBC u.h.f. transmitting stations but, despite this, the engineering planning problems encountered have been less severe than those relating to Lewis and Argyll. Surveys have shown that it will be possible to feed the Orkney station by direct radio pick-up of the Rumster Forest u.h.f. main station in Caithness but that it will not be possible to feed the Shetland station by direct radio pick-up of Orkney. A radio pick-up station will therefore be built on Fairisle and the signal transmitted to Shetland via a one-hop radio link. Fairisle has a very small population indeed and virtually no amenities, so that the radio link and pick-up station will need to be completely automatic and to have its own power supply.

Surveys have also shown that, although the existing v.h.f. television site on Shetland can be used for the u.h.f. installation, a new site is necessary to achieve the required coverage on Orkney.

3.2 Wales

Fig. 2 shows the locations of the Welsh main stations and outlines the plan for serving the more remote and mountainous areas. It will be seen that the six u.h.f. main stations providing basic coverage have been sited to serve the populated and relatively flat coastal areas and that the coverage of the remainder of Wales will be achieved by a number of networks of relay stations. The main stations and a number of large relay stations will serve as 'lighthouses' feeding chains of relay stations serving the more remote areas.

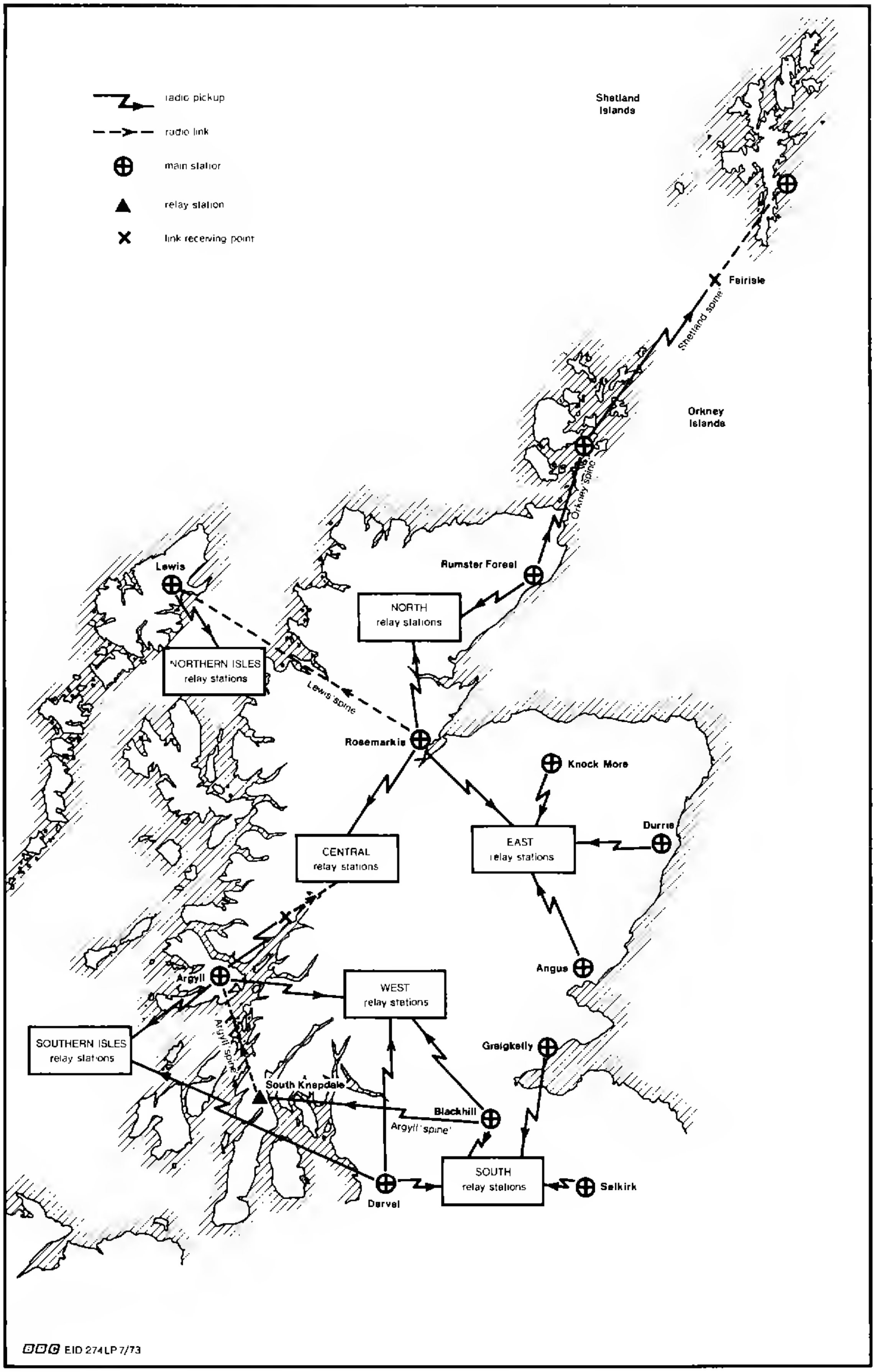


Fig. 1 UHF Coverage Plan for Scotland

The coverage problems in Wales differ from those in Scotland where the main difficulties concern access, the need to provide long and expensive radio links and the difficulties encountered in building in remote and relatively undeveloped areas. In Wales a very large number of relay stations is required in a relatively small geographical area and the main problems are posed by common channel operation and the need to avoid long chains of relay stations, each fed by radio pick-up of its neighbour. In chains of this type there is a progressive deterioration of picture quality and reliability and the total number of stations should not exceed three if an acceptable service to the viewer is to be provided.

The relay station construction programme in Wales to date has concentrated largely on the coverage of the densely populated South Wales valleys in Glamorgan and Monmouth where, eventually, some fifty stations will be built. But attention is now being concentrated on the more remote and less populated areas and, in particular, on mid-Wales and north-east Wales.

3.2.1 Mid-Wales

Coverage of the more southerly areas of mid-Wales will be based on a large relay station at Llandrindod Wells fed from the Carmel u.h.f. main station. The coverage of the more northerly areas of mid-Wales will be based on a large relay station at Long Mountain near Welshpool. The Long Mountain station is, unfortunately, remote from any of the Welsh main stations and will need to be fed by a long radio link from Blaen Plwyf. These two key stations will serve the Llandrindod Wells and Welshpool areas and, in addition, will act as 'lighthouses', providing direct radio feeds to a number of areas including Llanfylling, Llanfair, Llanidloes and Newtown.

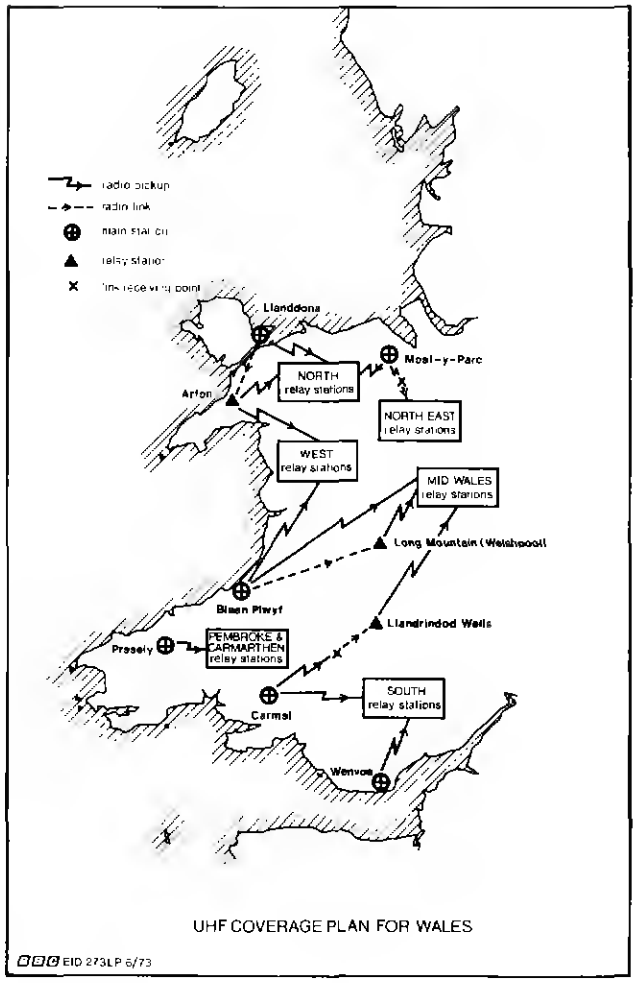


Fig. 2 UHF Coverage Plan for Wales

3.2.2 North-East Wales

For topographical reasons, the u.h.f. coverage of north-east Wales presents a particularly difficult problem. The mountainous areas of Wales shield the area from the Moel-y-Parc main station but, because of the flat terrain to the east, it is exposed to interference from u.h.f. transmitting stations in north-west England. As a result, there is a high incidence of common-channel interference, which restricts the number of relay stations that can be accommodated. A detailed study of the topography and of the distribution of population in the area is therefore being made to establish the optimum arrangement of relay stations. The problem is particularly acute at Wrexham, where it was originally planned to build a high-power relay station supplemented by a number of smaller relay stations. But investigations have shown that it is very difficult to allocate four adjacent interference-free channels for BBC-1, BBC-2, the IBA programme and the fourth programme. In view of the importance of the area, however, the possibility of a two-channel station to cover the Welsh-speaking part of the Wrexham area is being considered. This may be an acceptable solution to the problem, as the Wrexham area will receive an English service from the Shropshire main u.h.f. station which is due in service in 1975.

UHF Relay Stations: Distribution Transformers for use with the Standard Horizontally-polarised RBL Aerial

G. H. Millard, M.Inst.P.

Research Department

Summary: UHF relay stations obtain programmes by direct reception of a parent station and then re-transmit them on different channels. The receiving aerials used have to perform to much higher standards than the typical domestic receiving aerial and in particular must have much more discrimination against interfering signals. This is achieved by carefully controlling the contributions from different parts of the aerial using printed-circuit transformers. The article describes the design of two of these transformers.

Contents

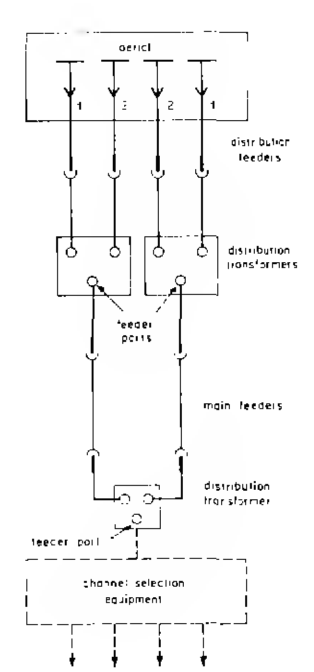


Fig. 1 Receiving aerial feed arrangements at low-power UHF relay stations

1 Introduction

The original design of re-broadcast link (RBL) aerial employed a coaxial distribution transformer. This design was changed by the manufacturing contractor to one using printed-circuit boards. The first design to be described, a four-way transformer, is an alternative to the contractor's design, so that the supply of trough aerials need not be confined to one manufacturer.

At the high-power relay stations it is normal practice to install two RBL aerials in order to give reserve facilities. However, the wind loading of these aerials is fairly high so that it is desirable for the low-power relay stations, which use a lighter-type of support tower, to use only one aerial. If reserve facilities are to be maintained it becomes necessary to feed the aerial in separate halves using the arrangement shown in Fig. 1. The second design to be described is a two-way transformer for this purpose.

Although the transformers were designed for use with a receiving aerial, the description of their behaviour is simpler if it is assumed that the system is transmitting and this practice will be adopted in the article. The principle of reciprocity states that an aerial system comprising linear, passive elements has identically the same directivity pattern for transmission and reception.

2 The Four-way Transformer

The highest impedance of the printed transmission lines was arbitrarily restricted to 100 ohms in order to avoid excessively narrow sections. Thus the sections immediately adjacent to the four inputs were chosen to have impedances of 100 ohms, 50 ohms, 50 ohms and 100 ohms in order to give the required current ratios. The remainder of the transformer was designed on the double-quarter-wave principle to give a source impedance of 50 ohms.

The general arrangement of the transformer is shown in

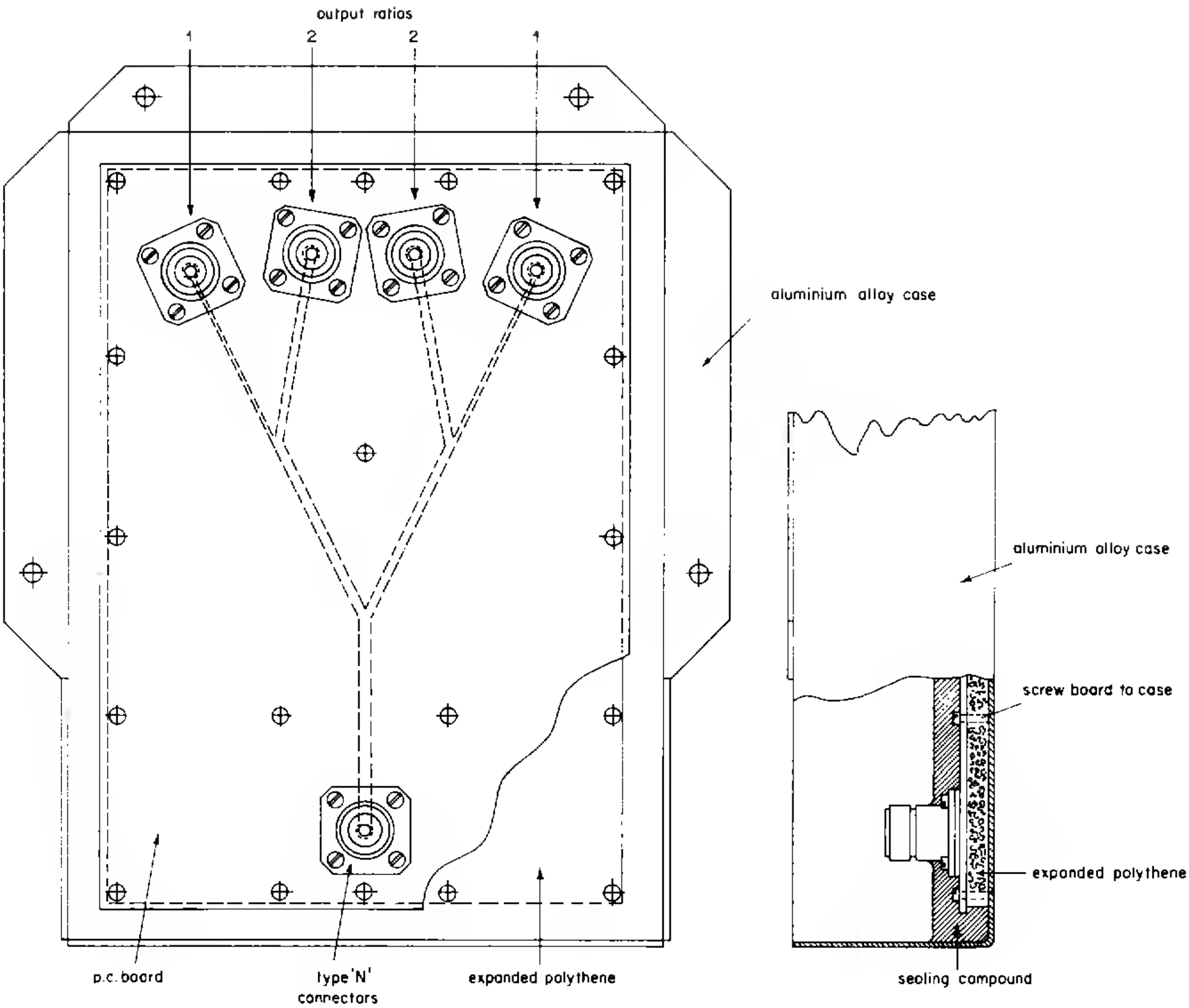
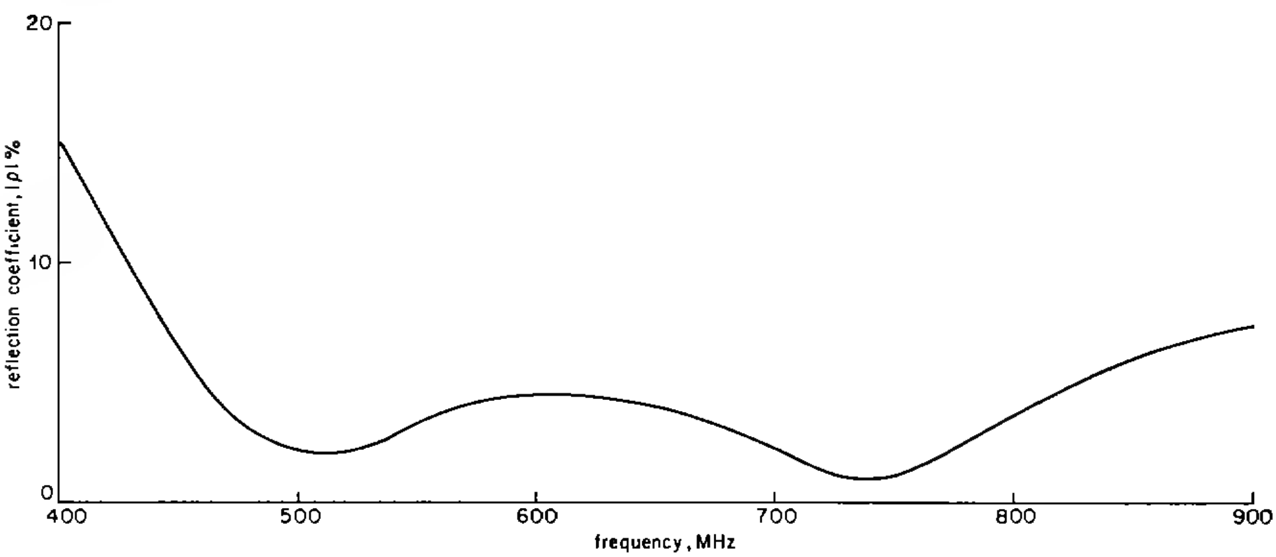


Fig. 2 Layout of four-way transformer

Fig. 3 Reflection coefficient of four-way transformer



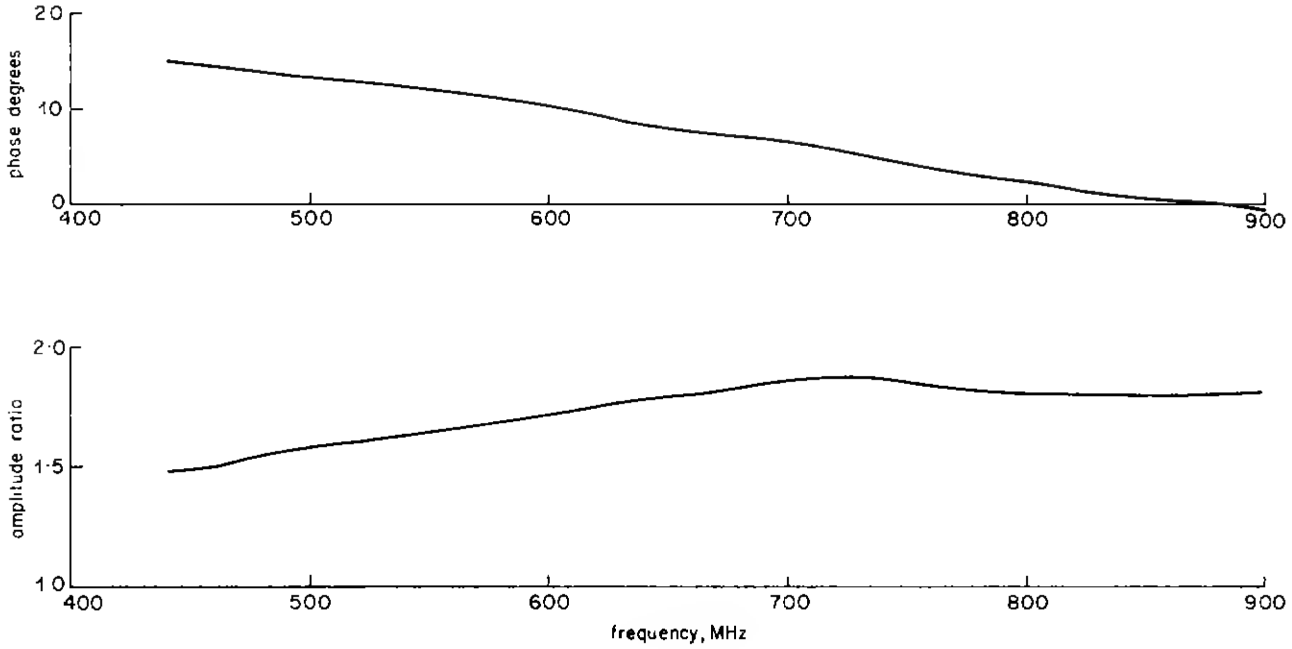
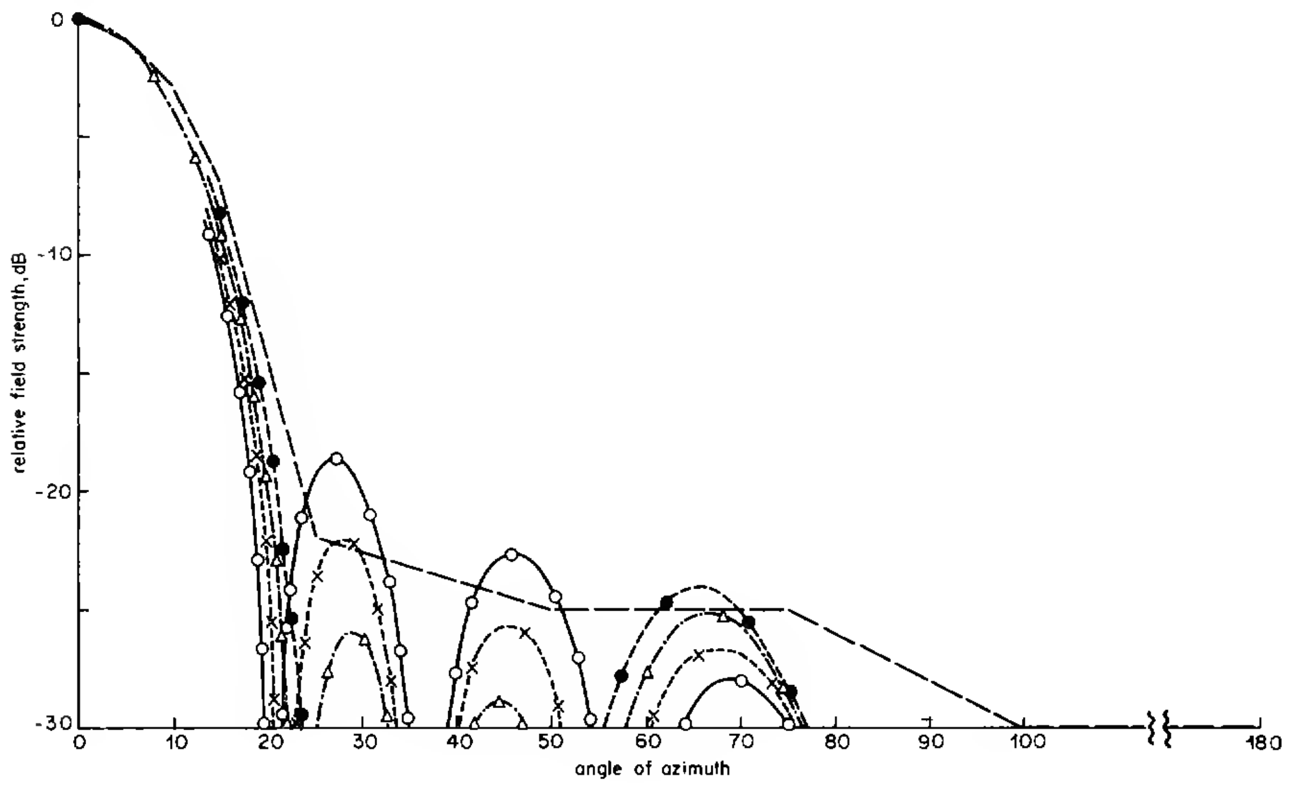


Fig. 4 Current ratio of four-way transformer

Fig. 5 Effect of current ratio on side-lobe level
o——— 1 : 1·5 : 1·5 : 1   x– – – 1 : 1·75 : 1·75 : 1   Δ — · — 1 : 2·0 : 2·0 : 1
● — — 1 : 2·25 : 2·25 : 1   — — Directivity assumed in calculating co-channel interference



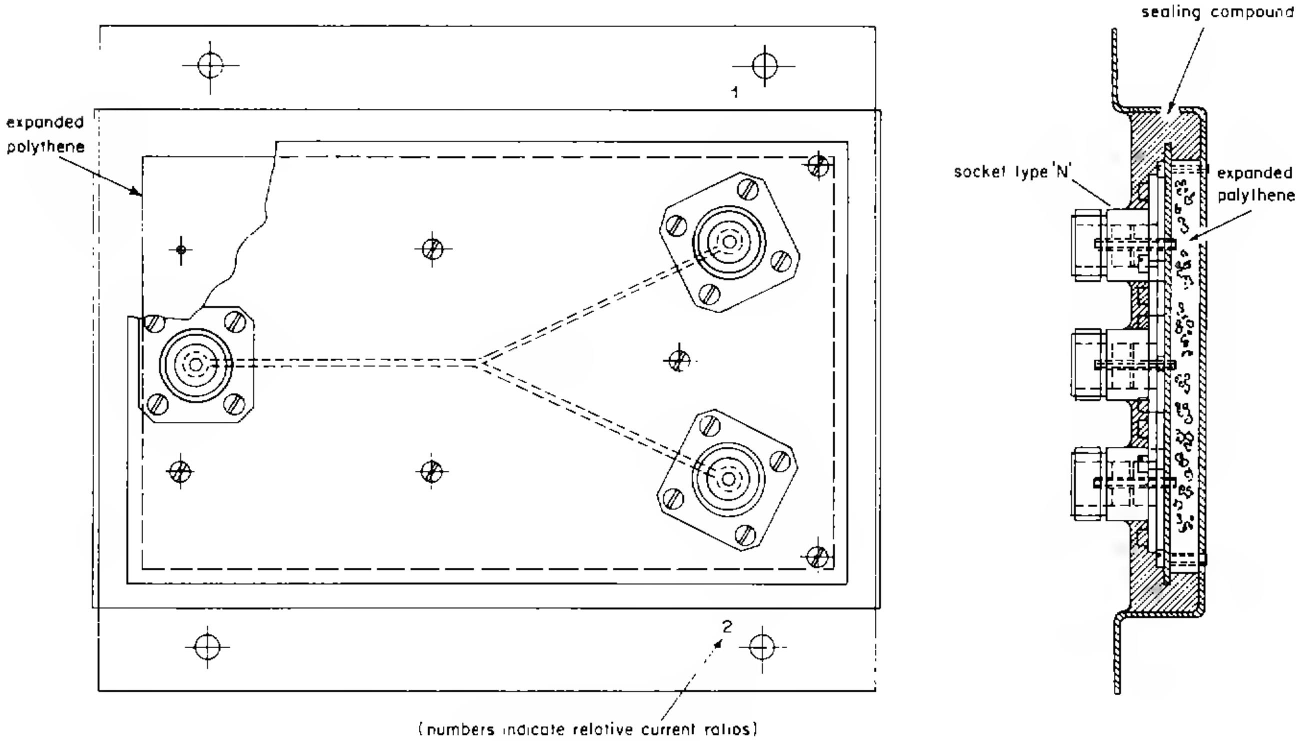
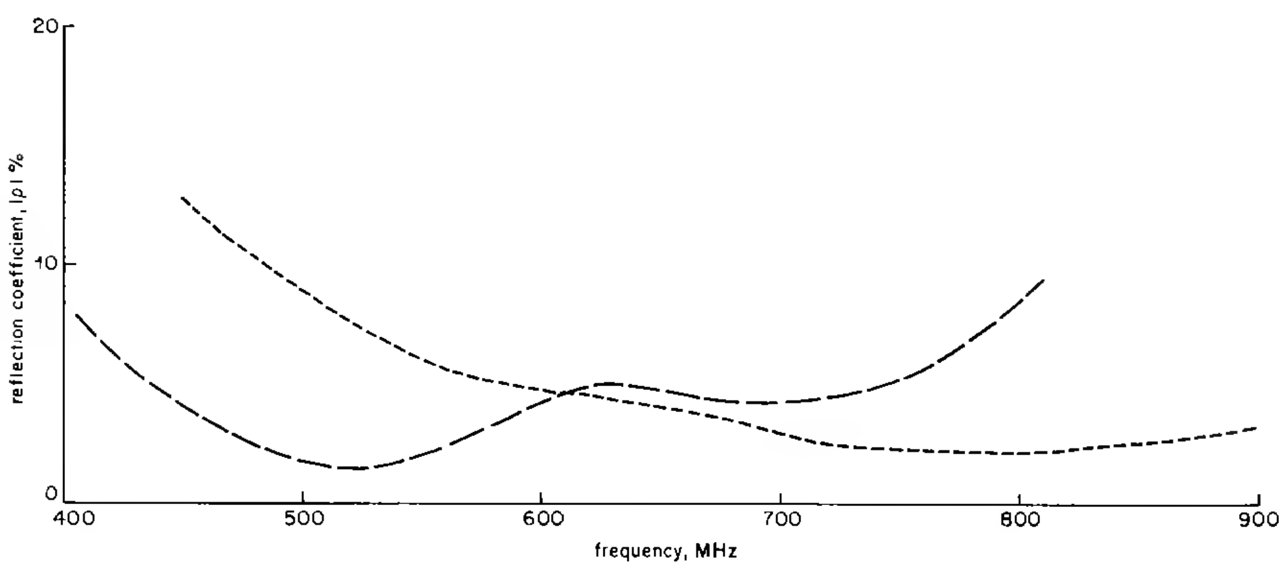


Fig. 6 Layout of two-way transformers

Fig. 7 Reflection coefficient of two-way transformers — — — Band IV Model - - - - - Band V Model



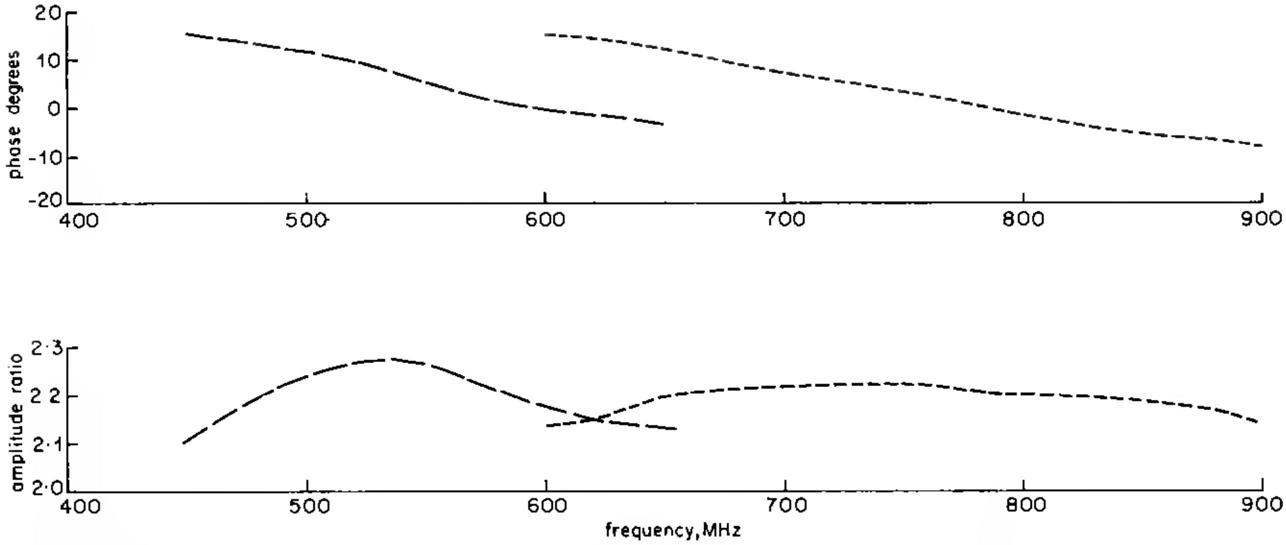


Fig. 8 Output ratios of two-way transformers — — — Band IV Model - - - - - Band V Model

Fig. 9 Horizontal radiation pattern of RBL aerial under emergency conditions
— — — — $0{\cdot}9\ f_0$ ——— f_0, mid-band frequency - - - - - $1{\cdot}1\ f_0$

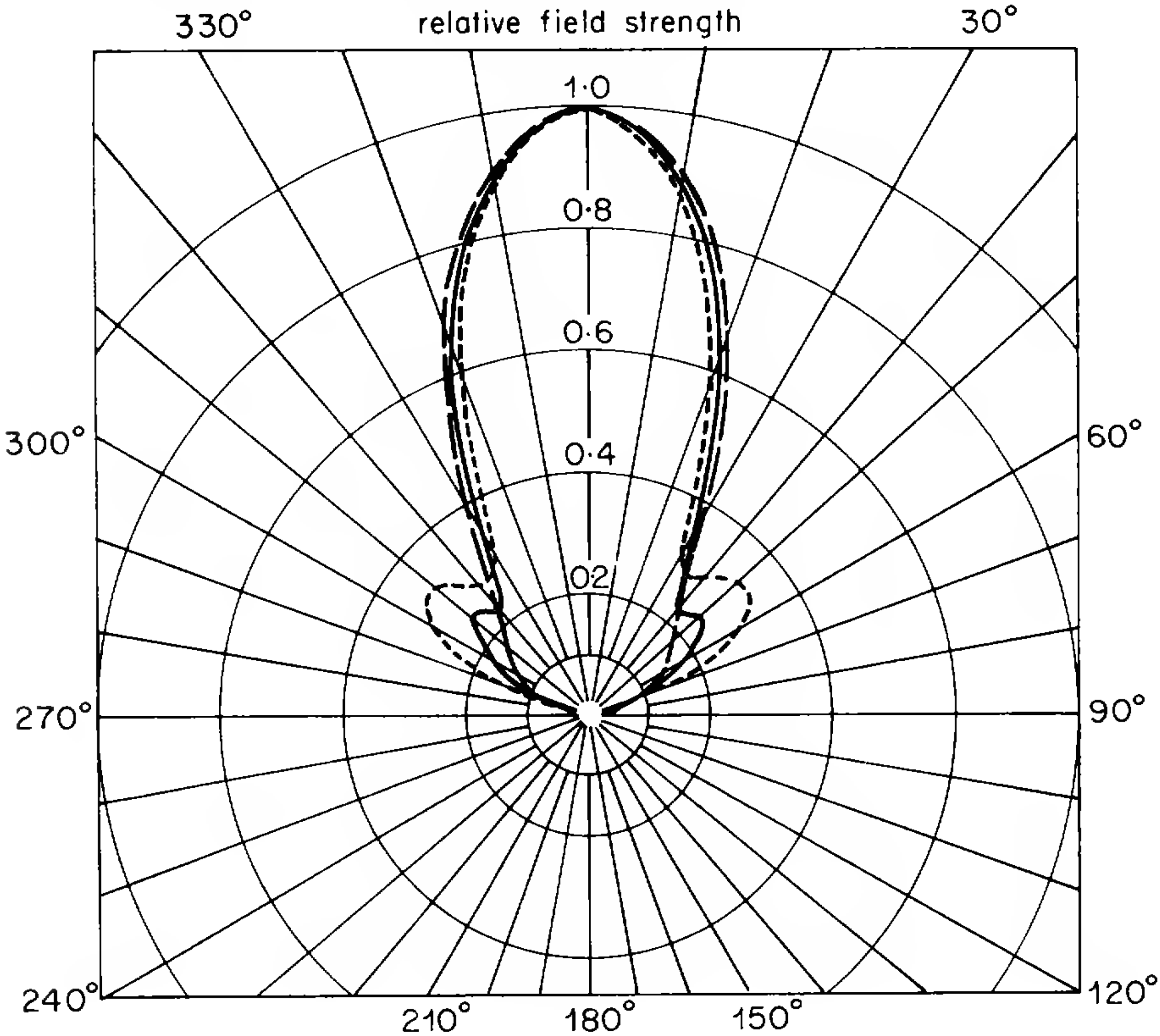


Fig. 2. MG51 laminate, copper-clad on both sides, is used with one side carrying the strip lines and the other providing the ground plane. The printed circuit board is mounted in an aluminium alloy tray and sealed with a flexible potting compound.

The return loss of the transformer when terminated with the aerial elements is specified to be not less than 17dB, corresponding to a voltage reflection coefficient of 14 per cent. The reflection coefficient of the transformer alone should therefore be appreciably less than this. Fig. 3 shows that the reflection coefficient does not exceed 6 per cent over the whole u.h.f. band.

Fig. 4 gives the variation of current ratio with frequency. As there is some departure from the nominal ratio of 1:2:2:1, it is of interest to examine the effect of the ratio on the h.r.p. Fig. 5 shows the side-lobe levels obtained with various current ratios and it will be seen that the side-lobe levels are less than those normally assumed provided that the ratio lies in the range 1·75–2·0. In the lowest part of the frequency range the ratio falls to 1·5 giving one side-lobe which is 3·5dB greater than that usually assumed; it was thought that this did not justify producing a separate design for Band IV, as was originally intended, since a pair of the two-way transformers could be used if any particular difficulty should arise.

The dissipative loss in the transformer is 0·3dB.

3 The Two-way Transformer

This was designed to give optimum performance with three line sections.[1] The layout of the printed-circuit board and the assembly, shown in Fig. 6, are basically similar to those of the four-way transformer. Two versions of the design were produced to cover Bands IV and V respectively. Figs. 7 and 8 show respectively the variation with frequency of the reflection coefficient and the current ratio.

The horizontal radiation pattern of one half of a standard RBL trough aerial fed by the two-way transformer (i.e. the h.r.p. under emergency conditions) is shown in Fig. 9.

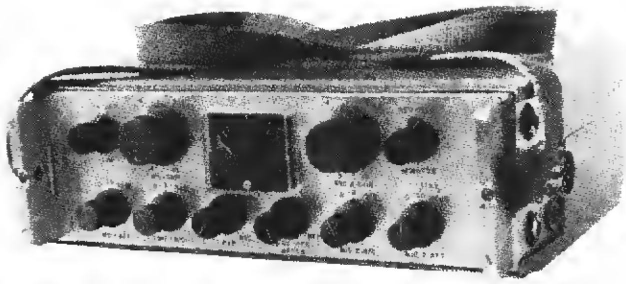
The dissipative loss in the transformer is 0·2dB.

4 Conclusions

Two designs of printed-circuit distribution transformer have been produced for use with the standard RBL aerial. The availability of these designs will help to keep down costs of relay station and will increase the flexibility of the RBL aerials.

5 Reference

1. Optimum parameters for a r.f. power-splitting network. BBC Research Department Report No. 1971/20.



Magnetic-stripe Recording Amplifier

The Magnetic Recording Amplifier AM15/503P is a battery-powered portable amplifier designed for use with motion-picture cameras using magnetic-striped film. The recording-chain comprises a two-channel mixer, a limiter and a recording-amplifier; input-signals at either line- or microphone-level can be accepted. A line amplifier delivers a feed of the signal from the recording-amplifier at a programme volume of —20dB. Replay facilities for headphone monitoring are provided, and a PPM circuit which can be switched to either the incoming or the reproduced signal. The meter of the PPM is used also to check the 50kHz recording bias and the battery voltage.

The amplifier is constructed on three printed-circuit boards which are plug-in units in a specially-constructed aluminium box. This, with two tubular containers housing the eight type-U2 (or equivalent) dry cells which power the amplifier, is accommodated in an outer carrying-case fitted with a leather strap handle. The total weight is 3·25kg.

'BBC Engineering, 1922–1972'; a correction

Mr Edward Pawley, the author of the book *BBC Engineering, 1922–1972*, informs us of an error in his book which has been pointed out to him by Dr George H. Brown of the David Sarnoff Research Center at Princeton, USA. On page 143 it is stated that the late Sir Isaac Shoenberg was a schoolfellow of David Sarnoff and Vladimir Zworykin in Russia. David Sarnoff, who is now eighty-two, has directly informed Dr Brown, however, that he first met Zworykin in 1929, and Vladimir Zworykin, who is now eighty-three, has told Dr Brown that he first met Shoenberg in 1936. Shoenberg was some ten years older than the other two men.

It is not disputed that these three men, each of whom made enormous contributions to electronics, were all of Russian origin.

Contributors to this issue

Geoff Higgs returned to England after eleven years of schooling in Canada and graduated with an external degree in Electrical Engineering (Telecommunications) from London University. He joined the BBC in 1963 and has been concerned throughout his BBC career with video tape recordings. He has been abroad on editing assignments with a number of BBC Television's major overseas sports transmissions such as the Winter Olympics at Grenoble in 1968, the World Cup at Guadalajara in Mexico in 1970 and the Summer Olympics at Munich in 1972.

Donald McGregor joined the BBC in 1955 working at Lime Grove Television Studios in the Central Apparatus Room and Presentation Studio. In 1960 he moved to Television Centre and in 1967 was appointed Assistant (Presentation) Central Operations. In 1971 he was appointed Assistant (Operations) Television Studios and coordinates the provision of facilities for complex or special programmes.

Derek Fawcitt joined the BBC in 1954, working in London Control Room as a Technical Assistant and Engineer until 1958 when he transferred to the Television Service. Since then he has been in the Video Tape Recording Section of Television Recording Department, initially as an engineer but as a Supervisor and Shift Manager since 1972. In his present appointment of Video Tape Operations Manager, he is responsible for all operations involving the recording, editing and transmission of programmes on video tape at Television Centre and Lime Grove.

Gerald Millard joined the BBC in 1951 after taking a degree in physics at the University of Manchester. Apart from an attachment of fifteen months to Aerial Unit, Transmitter Planning and Installation Department, he has been with Radio Frequency Group of Research Department. After early work on m.f., h.f. and v.h.f. aerials and measurement techniques, Mr Millard has been concerned with the development of the u.h.f. transmitter network and has contributed to the design of both main and relay station aerials.

William Wharton joined the BBC in 1938 and worked in the Radio Frequency Section of Research Department. After war service in the Royal Corps of Signals he returned to Research Department in 1946 and worked first in the Acoustics Section and then in the Aerial Section.

In 1953 he joined the Aerial Unit in Planning and Installation Department and was responsible for the planning of the aerial and combining unit systems for the medium- and low-power Band I television stations and for the v.h.f./f.m. transmitter network.

In 1960 he returned to Research Department as Head of Aerial Section and in 1962 became Head of Special Studies Section, where he was involved in the early stages of development of the BBC field-store standards converter.

In 1966 he became Head of Transmitter Planning Section in Transmitter Planning and Installation Department (now Transmitter Capital Projects Department). He became Head of Transmitter Capital Projects Department in 1968.